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THE UNIVERSITY OF ALBERTA

Factors Influencing Bus Passenger Wait Time in Edmonton

by

Marcel Joseph Huculak

(C)

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF Master of Science

Department of Civil Engineering

EDMONTON, ALBERTA

Fall of 1990

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled Factors Influencing Bus Passenger Wait Time in Edmonton submitted by Marcel Joseph Huculak in partial fulfilment of the requirements for the degree of Master of Science.

.....

Supervisor

.....

.....

Date OCTOBER 2, 1990

To Dad

I Love You

Abstract

Residential-end waiting times of bus passengers at bus stops in Edmonton, Canada were studied in this research. Previous research gave little attention to the effects of passenger attributes. Thus this study examined the influence of passenger trip purpose, schedule knowledge, and experience catching buses upon waiting time. Also examined were the influences of day to day weather and of persons arriving in groups.

A data collection method was designed to minimize the impact of the observer on bus driver and bus passenger behavior. The method used passenger interviews to link observed wait times with passenger attribute data. Detailed are the successes and failures of this obtrusive observation technique.

Data analysis was guided by statistical procedures. It was found that weather did not have a significant effect on the observed waits, although the range of observed weather was small. In contrast, groups tended to change their arrival behavior during less favorable weather. Although trip purpose did not have a strong effect, both experience and schedule knowledge had significant effects on passenger waits. Applications of these findings and recommendations for further research are given to direct future research.

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The author would like to acknowledge those persons and organizations who helped to complete this research effort. It is hoped that all contirbutions are recognized. Any ommissions are accidental and are not intended.

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the determination to complete this research in the face of personal adversity.

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1. Introduction

1.1 Purpose

The purpose of this research is to gain a better understanding of some factors which affect bus passenger waiting time. Many factors affect wait time. A literature review is used to guide this research, by showing which factors have or have not been studied.

Many types of wait times can be defined. In this research, only waits where passengers are free to choose their bus stop arrival times and where bus arrival times are reliable are studied. A passenger's arrival time must not be controlled by the end-time of another activity, such as another bus arriving (for transfers) or as passengers arriving at a stop immediately after leaving work. Reliable bus arrival times mean that a bus's day to day arrival time does not change during a particular schedule period (eg. Monday to Friday, AM Peak).

Although this research will study "bus" passenger wait time, it is applicable to other similar modes of public transport. The importance of wait time studies, providing motivation for this research, is outlined below.

1.2 Importance of Waiting Time

Rohr (1990), in developing a marketing segmentation method for public transport, referred to the importance of wait time, stating "...two key public transport attributes

which affect whether individuals will choose public transport or not are the walk times from their homes to their transit stops and their wait times." Passengers often view wait time as one of the most inconvenient portion of a bus trip. Their goal is to travel, yet they are stationary. Waiting passengers may also experience discomfort due to lack of shelter or place to rest. To reflect this inconvenience, mode split models (calibrated from measured travel behavior) often weight the waiting time portion of a bus trip by two to three times as much as the in-bus travel time (It should be noted that Hunt (1988) developed a mode split model which did not explicitly include origin wait time). A better understanding of wait time may lead to measures which reduce wait time, and improve passenger perceptions of the bus system.

A better understanding of wait time can also help improve wait time models. Such models provide input into mode split models used for transportation planning. Mode split models can be sensitive to relatively small changes in wait time.

Wait time models are also used to evaluate system performance. Often, changes in service will change wait times. An accurate assessment of possible changes in wait time can help evaluate the benefits and costs of a service change.

Wait time is perceived as inconvenient by passengers. Wait time models are important input into mode split models,

and into system performance evaluation. A better understanding of some of the factors affecting wait time may help to improve passenger perceptions and wait time models.

1.3 Summary of Contents

Past research on bus passenger waiting time is reviewed, and results pertaining to factors affecting wait time are presented. The review identifies the factors to be studied. A Proposed Data Collection Methodology Section details how data on the factors studied was to be collected. Then the actual data collection procedure is described, attending mostly to problems encountered. The collected data is then analyzed. The Analysis Section describes the analysis techniques used and their results. The Conclusions and Recommendations summarize the results of the research, and recommend applications of the results as well as areas in need of further study.

2. Past Research on Bus Passenger Wait Time

2.1 Introduction

This review of past literature serves two purposes:

1. to summarize the findings of research related to factors affecting bus passenger waiting time
2. to use this summary to formulate the research objective.

The past research is presented in chronological order. Each researcher's findings are summarized with respect to the factors affecting wait time and to the effect of these factors. These findings are summarized at the conclusion of this chapter.

2.2 Holroyd and Scraggs (1966)

These two researchers did not actually measure passenger wait times. Instead, they measured bus headways in Central London, England, and estimated wait times by assuming random passenger arrivals during the observation period. They acknowledged that this assumption would not hold for infrequent services, but did not attempt to determine the headway of an infrequent service. They instead limited the study to average headways of less then 10 minutes.

Their formula for estimating wait times for a given observed set of bus headways was as follows:

$$\bar{w} = \frac{\Sigma_i \, n_i (h_i/2)}{\Sigma_i \, n_i}$$

substituting $n_i = h_i$

$$\bar{w} = \frac{\Sigma_i \, h_i^2}{2\Sigma_i \, h_i}$$

where:

$\bar{w}$ = average wait time

n_i = number of passengers in bus headway i

h_i = length of headway i

In words, the average waiting time for randomly arriving passengers is the sum over all observed headways of the number of passengers in each headway h_i multiplied by their average wait $(h_i/2)$, divided by the total number of passengers observed. The number of passengers arriving in bus headway n_i is directly proportional to the length of headway h_i

Holroyd and Scraggs (1966) then applied a correction to the above formula for incomplete headways falling on the "edges" of the observation period. The formula shown above is given by several other researchers, and assumes that passenger arrivals are random and that passengers are able to board the first bus available.

Holroyd and Scraggs (1966) found that for average headways ($\bar{h}$) less than or equal to 2 minutes, the estimated wait time is similar to the case of randomly arriving buses

and passengers (i.e. $\bar{w} = \bar{h}$), while for longer headways average wait times approached that of randomly arriving passengers with perfectly regular bus arrivals ($\bar{w} = \bar{h}/2$).

2.3 Gill (1969)

This 1969 thesis dealt mainly with bus routing in Edmonton, Alberta. However, there was some discussion of waiting time.

Gill (1969) recognized that elements of bus excess time such as waiting time "...depend on the frequency of service unless the schedule is known." He implies that some knowledge of the bus system can affect waiting time.

As part of his research, Gill (1969) handed out questionaires to waiting AM peak passengers, which were returned before boarding. He also measured waits for these passengers. One of the questions asked what time the bus arrived at the stop. He found that 98% of the passengers knew the bus arrival time, although he did not state what criterion were used to judge responses. This concurs with the findings of Bowman and Turnquist's (1981) wait time model for AM peak Chicago area bus passengers.

Gill (1969) found that the mean waiting time for these passengers was 3.88 minutes, for a minimum headway of 20 minutes. He stated that for other times of day, wait times may be longer as passengers may be less familiar with schedules.

It appears that Gill's (1969) passengers were basing their questionaire responses upon experience, not a published schedule. Therefore, the question is more likely a measure of experience using the bus, not schedule knowledge. Nonetheless, by using a quesionaire procedure Gill (1969) was able to link wait time data to passenger data.

2.4 O'Flaherty and Mangan (1970)

O'Flaherty and Mangan (1970) examined the relation between average headway and average passenger wait time for PM peak and offpeak conditions in Leeds, England. Wait times were measured for the PM peak conditions. For the offpeak data, actual passenger wait times were not measured, but were estimated by the same formula as Holroyd and Scraggs (1966).

For the PM peak measurements, they found that actual passenger wait times tended to be less than half the headway for headways greater than about 5 minutes. This was a significant finding. They had found a definition of an "infrequent service". Later researchers also defined the headway at which passenger arrivals cease to be random.

O'Flaherty and Mangan (1970) also observed that as the average bus frequency decreased by a factor of ten (from 1.2 minutes to 12 minutes), the measured average wait time increased only by a factor of 1.75 (from 2.0 minutes to 3.5 minutes). This illustrates the inelastic nature of average wait time with respect to service frequency.

2.5 Seddon and Day (1974)

These two researchers observed wait times during AM peak, offpeak and PM peak periods in Manchester, England. Observed headways ranged from 4 to 30 minutes. They wished to determine the headway at which passenger arrivals cease to be random.

For their data, they found passengers do not arrive randomly at headways around 10 to 12 minutes. This differs from O'Flaherty and Mangan (1970). Seddon and Day (1974) did not refer to O'Flaherty and Mangan's (1970) research, although it is likely that the discrepancy is due to the time periods at which the observations were made and the type of stops observed. Seddon and Day (1974) were quite explicit in describing the stop types observed, while it is unknown what stop types O'Flaherty and Mangan (1970) observed.

Seddon and Day (1974) also concluded that using the formula which assumes random passenger arrivals (as given in the Holroyd and Scraggs (1966) section) overestimates the observed wait time, and that in general the overestimation increases as the headway increases.

2.6 Okrent (1974)

The objectives of Okrent's (1974) thesis research were:

1. to determine the condition in which passenger arrivals are uncoordinated with vehicle arrivals.
2. to produce a model of passenger arrivals when

passenger arrivals are not coordinated with vehicles arrivals.

Okrent (1974) formulated a hypothesis of passenger arrival time coordination with vehicle arrivals. He gave the degree of coordination as a function of:

1. System characteristics:
   a. Headway - longer headways have more "coordination" because of greater potential to reduce wait time.
   b. Reliability of Service - more coordination with better reliability.
   c. Easily Known Schedule - either a simple schedule (i.e. clock headways) or one which is well publicized.
2. Trip Characteristics:
   a. Familiarity with the service - a rider's experience with a particular service.
   b. Flexibility - if trip departure and arrival times are unimportant the passenger may not care about time wasted at a stop. Conversely, passengers may not arrive at the stop until the bus is due to arrive. They may pass time "window shopping" or doing some other activity, then rush to the stop when the bus arrives.

Okrent (1974) identified that a passenger's experience "catching the bus" may influence wait time (Note: "Catching the bus" is a colloquial expression meaning that passengers

"arrive in time to board" a bus. Because of its relative brevity, "catching the bus" will be used throughout this thesis). Previous researchers mostly considered bus system characteristics only (i.e. headways), and implicitly assumed a homogeneous population of passengers. In a sense, Okrent (1974) turned the tables around. He considers that passengers may influence their own waiting time rather than simply the bus's influence on the passenger's wait.

Unfortunately, Okrent (1974) did not investigate the effect of passenger experience on wait time. Only headway and reliability were studied. Futhermore, he used the standard deviation of headways as a measure of reliability. Although he shows that the standard deviation of headways and of bus arrival times are related, he assumes that each bus at a particular stop has the same degree of day to day reliability. This may not be true, as changing traffic conditions through a day may govern bus reliabilities at a given time of day. Also, different bus drivers may have different reliabilities. Therefore, the standard deviation of headways may not reflect the day to day reliability that a passenger faces (although for some passengers, who may catch different buses on different days at the same stop, an aggregate reliability of all buses may be more appropriate).

Okrent (1974) observed a variety of Chicago, Illinois, area bus stops at a variety of times (AM peak, midday, Saturday, and PM). Locations selected provided a broad range of headways and service reliabilties. Average headways

varied from 5.8 minutes to 30 minutes.

He found that as the average headway exceeds 13 minutes, the uniform random passenger arrival assumption must be rejected. For stops where $\bar{h}$ > 13 minutes but arrivals were still random, he explained that given the time of day for these observations (Saturday and Noon), trip purpose (i.e. shopping) likely played a role and thus patrons were less familiar with the service. Again Okrent (1974) has an unique perspective. He implies that either trip purpose or experience (or both) influence a passenger's wait time.

Okrent (1974) points out that studying trip purpose or experience is possible. Passengers could be interviewed for experience and trip purpose, and the effects of these variables on waiting time could be analysed. He further recommended that effects upon wait time such as adverse weather, waiting shelters and night time conditions be studied.

2.7 Jolliffe and Hutchinson (1975)

Jolliffe and Hutchinson (1975) used a behavioral approach to explain bus passenger wait time. From some of the above past research they knew that for certain headways passengers did not arrive randomly at stops. They explained this by considering passengers to be one of three possible types:

1. a proportion q whose arrival time is casually

coincidental with the bus

2. a proportion p(1-q) who arrive at the optimal time (the time at which the expected waiting time is a minimum)

3. a proportion (1-p)(1-q) who arrive at random.

Casually coincidental arrivals were defined as passengers who, while perhaps shopping or doing some other activity, see the bus approaching, drop their activity, and run to the bus stop. Expected wait time was defined as the average, over all days observed, of the time elapsing before the next bus departs, for each minute in the observation period.

Jolliffe and Hutchinson (1975) provide support for their hypothesis by arguing that "...if there is a published timetable for the service, or if buses tend to run at certain fixed times rather than at others and there are some passengers who frequently make the same journey, then it may be expected that the bus and passenger arrival times at the stop will be associated so as to reduce the average waiting below that given by..." assuming random passenger arrivals. This argument implies the importance of passenger experience catching the bus. They further state that the gain in reduced waiting time is affected by the extent that buses arrive at the same time from day to day, rather than the regularity of the service from day to day. That is, it is better for buses to arrive at 7:10, 7:15, 7:30, 7:45 on consequetive days rather than arriving at 7:00, 7:15, 7:30, 7:45 one day, 7:10, 7:25, 7:40, 7:55 the next and then 7:05,

7:20, 7:35, 7:50 on the third day.

Jolliffe and Hutchinson (1975) felt that their model of wait time worked well for the data they collected in the south London suburbs, because they felt that the proportions p and q are likely related to:

1. the time of day
2. the socio-economic characteristics of the passengers
3. the type of development near the stop.

in a simpler way than average wait time itself.

2.8 Chapman, Gault and Jenkins (1976)

These researchers did not study passenger wait time, but instead studied urban bus route operations. They did, however, touch upon some aspects of wait time.

They felt that passenger wait time depended on:

1. schedule frequency
2. passengers' knowledge of the timetable and their experience with actual service
3. evenness of headways (for short heaway services).

Again, experience and schedule knowledge are identified as influences on wait time, but no further investigation is made.

Chapman, et al (1976) went on to critize the analysis procedures of O'Flaherty and Mangan (1970) and Seddon and Day (1974). Chapman, et al (1976) noted that these researchers measured actual arrivals of passengers and buses, calculated an average wait time then compared it to a

theoretical average wait time from an appropriate headway distribution. This is a roundabout way of testing for random arrivals; a Chi-Squared test on the wait time distributions would have sufficed.

2.9 Jackson (1977)

Jackson's 1977 thesis studied passenger waiting time in Toronto, Ontario. Much of his research associates individual passenger interview data with wait time data. The interview tested each passenger's knowledge of bus arrival times. Depending on the interviewed passengers' accuracy, they were classified as either a random or non-random arrivals. Jackson (1977) felt that his interview classification method was successful.

Although Jackson (1977) states that he examined passenger schedule knowledge, it appears that he actually measured passenger experience catching buses at the observed stops. He defined schedule knowledge "...as the time difference between a passenger's anticipated bus arrival [as stated in the interview] and the scheduled bus arrival." But since the observed stops were not timing points, he defined scheduled bus arrival as the observed average arrival time of the bus. Thus his schedule knowledge actually measures experience, as a passenger would need to experience bus arrivals on several days to correctly estimate the average bus arrival time. Jackson (1977) even admits that a passenger "...learns the scheduled bus arrival time by

observation and trial and error." He concluded that there is evidence to suggest peak users know "schedules" better than offpeak users. In the context of experience, this seems reasonable. During peak periods, trips are more regular and thus experience measured would be higher than during offpeak periods.

In analysing his data, Jackson (1977) found a difference between random and non-random interviewed passenger arrival distributions for 12 and 15 minute headways, but differences for the 5 and 10 minute headways were not as great. Jackson (1977) also tested a stop with a 25 minute headway, but results from it are ignored in the summary. The stop was near an apartment and Jackson (1977) felt that some passengers were waiting inside the building.

Jackson (1977) also found a problem with his interview technique for distinguishing random arrivals. For longer headways, passengers that were defined as random arrivals did not tend to arrive randomly. He explained this by stating that while passengers "...may express ignorance of the bus schedule when interviewed, they, in fact, are not behaving like true random arrivals." Despite this problem, he still felt that "...the hypothesis that passengers who express no knowledge of schedule arrive according to a uniform distribution appears to be reasonable."

Jackson (1977) examined the proportion of random and non-random arrivals for particular headways. Generally he found:

1. that the proportion of random arrivals decreases with increasing headway
2. that, for similar headways, the proportion of random arrivals is higher for offpeak passengers.

The first finding is likely due to a lower proportion of "non-transit captives" avoiding an infrequent service. The second finding is likely a function of trip purpose (i.e. work trips versus shopping trips). Shopping trips are also less frequent, and thus these passengers are relatively less familiar with the service.

Jackson (1977) examined "safety margin" - "The time difference between his [a passenger's] arrival at a stop and his anticipated bus arrival time." He concluded that "...it appears that longer headways elicit greater margins of safety but this increase is small compared to the penalty (the bus headway) for missing the bus." This is consistent with O'Flaherty and Mangan's (1970) finding that wait time is inelastic with headways.

Jackson (1977) also recognized that weather may influence waits. Therefore, he did not survey "...during periods of precipitation or extreme temperature."

2.10 Turnquist (1978)

The objectives of this study were twofold:

1. to produce a wait time model with explicit treatment of non-random passenger arrivals
2. to incorporate the effect of day to day reliability

on passenger wait time.

Turnquist (1978) uses a similar argument as Jolliffe and Hutchinson (1975) to explain non-random arrivals. He states "...if buses tend to adhere to a fixed schedule and there are passengers who make the same trip frequently, it may be expected that some passengers will plan their arrival at the bus stop so as to be there just before the bus comes." Once again, passenger experience (via frequency of use) is implied as a key ingredient to reduce wait time. He differs from Jolliffe and Hutchinson (1975) with regard to casually coincidental arrivals. He feels that they are not a behaviorally distinct group, but rather that they belong to either random or non-random passenger arrival groups. Their behavior is then "...modified slightly as a result of seeing the bus coming."

Turnquist (1978) also differs from Jolliffe and Hutchinson (1975) in the treatment of non-random arrivals in his model. He assumes non-random arrivals minimize expected wait time subject to a constraint which fixes the probability of missing the selected bus. This reflects a more risk-aversive behavior. It appears to be a reasonable behavior mechanism given the findings by Jackson (1977) regarding "safety margin".

In the end, Turnquist (1978) presents a model predicting average passenger wait time at bus stops as a function of the headway distribution between successive buses and of the arrival time distribution of a given bus

from day to day. The model provided a means of predicting service change impacts.

2.11 Smith, Soland and Warmoes (1978)

Bus passenger wait times in Montreal, Quebec were observed by Smith, et al (1978) so that they could construct a statistical model of passenger arrival patterns and waiting times for use in evaluating transit operations. Passengers were observed in peak and offpeak conditions. They found that for headways of less than 4 minutes passenger arrivals were random, while for larger headways passenger arrivals were skew towards shorter wait times.

2.12 Bowman and Turnquist (1981)

Citing Okrent (1974), Jolliffe and Hutchinson (1975), Jackson (1977), and Turnquist (1978) as studies which separated passengers into "aware" and "unaware" of bus schedules, Bowman and Turnquist (1981) used this concept to develop a model which evaluates the sensitivity of expected (model predicted) passenger wait time at a bus stop to service frequency and schedule reliability. The model explicitly incorporates a passenger decision making process. It uses a logit formulation to model passengers who are "aware" of the schedule.

They calibrated the model to wait time data collected in Chicago and Evanston, Illinois during AM peak periods. They found that the proportion of "aware" passengers was

estimated as 1.0 for nearly all cases. This was attributed to the regular nature of AM peak trips, and matches findings with Gill's (1966) research.

Their model implied that wait time is "...much more sensitive to schedule reliability and much less sensitive to service frequency than previously thought."

2.13 Lam and Morrall (1982)

This is the only research to examine the effect of weather on bus passenger wait time. Lam and Morrall (1982) collected data in Calgary, Alberta during summer and winter seasons, and for a variety of stop types and times of day. They aggregated then analyzed each seasons' data, concluding that the hypothesis that average waiting times in summer are greater than in winter was supported by their data. However, they stated that the passenger populations are also different during these seasons, with more post-secondary and institutional (school) trips in winter, with summer vacations reducing the work force by 20-25%, and with more reliance on transit in winter, especially in very cold weather, when automobiles will not start or roads are hazardous. Thus the measured difference may be due to passenger populations rather than to seasonal weather.

Lam and Morrall (1982) found that using different analysis procedures may lead to differing conclusions regarding the headway at which passenger arrivals cease to be random. They first plotted average wait time against

average headway. They concluded that for average headways less than 10 minutes average waiting times were about half the average headway. For longer average headways, the average wait time was less than half the headway. However, when they used a Chi-Squared test procedure, they found that passenger arrivals were not random, but that passengers tended to arrive at the end of the headway. They attributed part of this finding to their observation that passengers were increasing their walking speeds to catch an approaching or waiting bus.

2.14 Hutchinson, Burt, Cuzner and Howell (1986)

Hutchinson, et al (1986) presented the same model of bus passenger wait time as Jolliffe and Hutchinson (1975). New data were collected in suburban Coventry, England, and they found that the model was still adequate. They added that because this model accounts for different passenger behavior, it can examine how policy changes affecting regularity (but not reliability) will impact each modelled passenger group.

2.15 Summary of Bus Passenger Wait Time Research

Generally, the past research has contributed new knowledge to four areas. First is the headway at which passenger arrivals cease to be random. It ranged from 4 to 13 minutes for the research discussed. Discrepancies arise because of the different analysis techniques used, because

of the different stop types observed, and because of the different transit systems observed.

The second contribution of the above reasearch is that the average wait time is inelastic with respect to headway.

The third contribution of the past research is identifying factors which affect wait time. Collectively these researchers found that wait time is, or may be, a function of:

1. Bus headway
2. Bus reliability (day to day punctuality of a particular bus)
3. Bus regularity (uniformity of headways)
4. Passenger experience catching the bus
5. Passenger schedule knowledge
6. Passenger trip purpose
7. Passenger socio-economic characteristics
8. Seasonal weather
9. Day to day weather
10. Type of land use near the stop
11. Night/day conditions
12. Shelter at the stop.

The first three factors received the most attention in the past reasearch.

Finally, the past research has contributed to the use of passenger interviews in wait time studies. Such interviews may be used to determine information about passengers, such as passenger trip purpose or schedule

knowledge. Interview data can also be linked to observed waits for analysis.

3. Research Objective

The past research has identified many factors which affect bus passenger waiting time. Most studies were directed at how bus operational parameters such as bus headways, reliabilities, and regularities affect average passenger waiting time.

Researchers such as Okrent (1974), Jolliffe and Hutchinson (1975), Jackson (1977), and Bowman and Turnquist (1981), among others, realized that passengers may also affect their waits, particularly if the bus service is reliable. These researchers felt that trip purpose, schedule knowledge, experience catching the bus, and socio-economic characteristics may affect measured wait times. However, limited actual research has been undertaken upon these factors, and often the methodology is unclear.

Other researchers, such as Jolliffe and Hutchinson (1975) and Jackson (1977), implied that time of day (i.e. peak versus offpeak) affects waiting times. However, it would seem that time of day merely describes the trip purpose or experience catching the bus that most passengers may have at that time of day.

During a preliminary study (Edmonton, Canada, June/July 1987, Route 18 at 118 Avenue - 38 Street), both experience catching the bus and schedule knowledge seemed to play a role for some passengers' wait times. The study observed the same stop for twenty nine consecutive weekdays. Passengers were identified by their physical characteristics as

remembered by the observed and their arrival times were recorded. Figure 3.1 shows a passenger who seemed to use her experience to catch the bus. She arrived at nearly the same time every day and usually caught the same bus every day.

During this preliminary study, the bus schedules were changed to match reduced summer passenger loads (bus headways were increased from 10 to 15 minutes). However, the newly published route brochures displayed the old schedule. It could be seen that some passengers were confused. Figure 3.2 illustrates one such passenger. His arrival times were very precise. After missing the bus due to the schedule change, his next arrival was his earliest observed arrival. He was trying to adjust his arrival time after "missing" the bus the previous day. Unfortunately this passenger (likely a student) was only observed twice after the schedule change.

Data for this preliminary study were not ideal. It was strongly suspected that the observer's presence affected some of the arrival time observations made. However, the study did tend to indicate that experience catching the bus and schedule knowledge both affect wait time. A better experimental design could help to measure these effects.

The past research emphasises the effects that bus operations may have on waiting time. Little attention has been paid to the passenger's perspective. Passenger trip purpose, schedule knowledge, and experience catching the bus seem to be the most frequently mentioned passenger variables that may affect passenger waiting times. Thus the objective

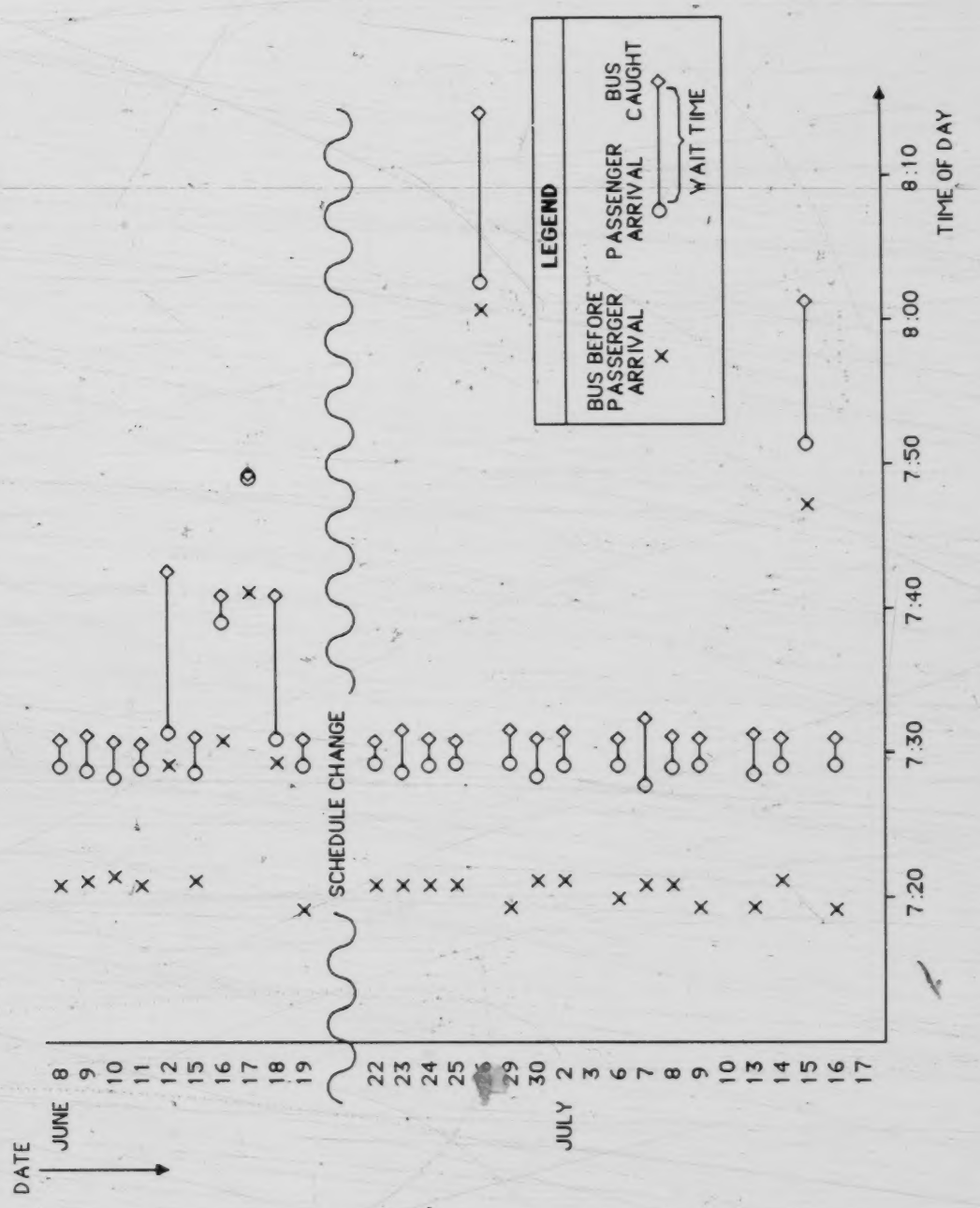

LEGEND
BUS BEFORE PASSENGER ARRIVAL
PASSENGER ARRIVAL
BUS CAUGHT
WAIT TIME
SCHEDULE CHANGE
DATE
JUNE 8 9 10 11 12 15 16 17 18 19 22 23 24 25 26 29 30
JULY 2 3 6 7 8 9 10 13 14 15 16 17
7:20 7:30 7:40 7:50 8:00 8:10
TIME OF DAY

Figure 3.1 An Experienced Bus Passenger's Arrival Times and Wait Times.

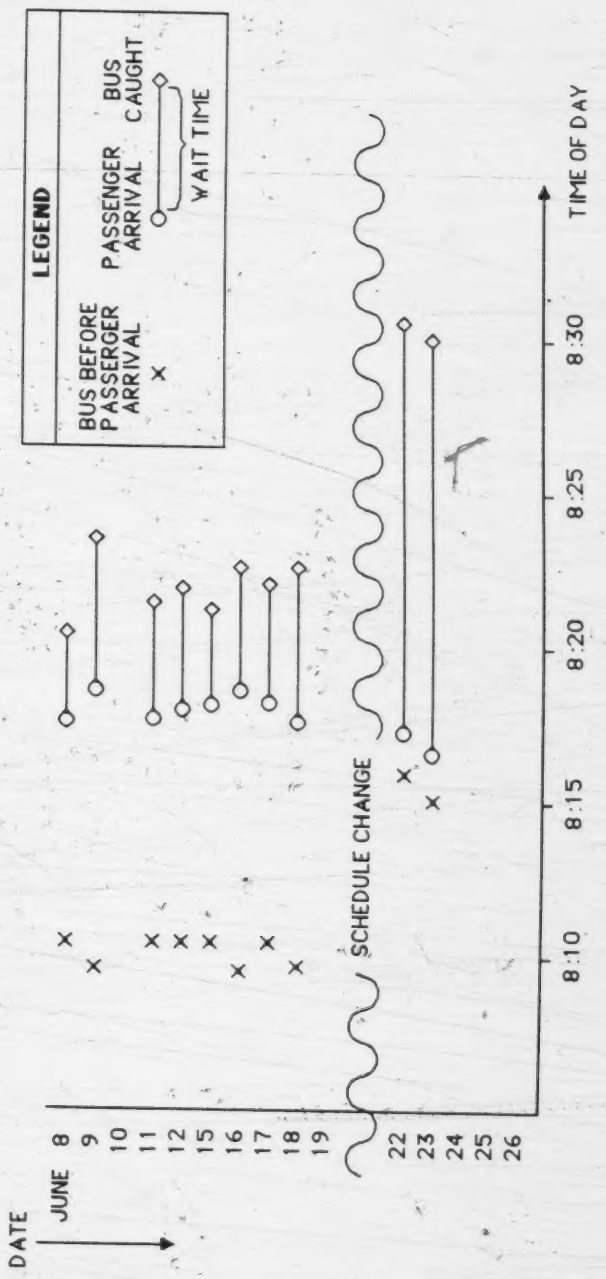


Figure 3.2 A Confused Passengers Arrival Times.

of this research is to examine the effect of passenger trip purpose, schedule knowledge, and experience catching the bus on passenger wait time at bus stops.

4. Proposed Data Collection Methodology

4.1 Introduction

This chapter's purpose is to address the research objective by identifying the data needs and by proposing a data collection methodology. The proposed data collection methodology explains the intended manner in which the data were to be collected. It was to anticipate practical and theoretical constraints so that data collection could proceed smoothly. Problems encountered by the proposed method, and changes thereby made, are described in the next chapter.

In this chapter the data needs are first identified by considering the research objective. Then the proposed data collection methodology is explained. Finally, the proposed data collection method is summarized.

4.2 Data Needs

The data needs arise from the reseach objective. From Chapter 3, the objective of this research is to examine the effect of passenger schedule knowledge, passenger experience catching the bus, and passenger trip purpose on bus passenger wait time at bus stops.

It is also thought that weather and arrivals of passengers in groups may effect waits. Neither of these variables can be controlled in the experimental design. Also, weather itself is of interest, especially in cities

such as Edmonton where weather can vary significantly.

Given the above discussion, data on the following items are required for this research:

1. Wait time- composed of a bus and a passenger arrival time
2. Weather
3. Type of arrival (group or individual)
4. Passenger data
   a. Experience catching buses
   b. Schedule Knowledge
   c. Trip Purpose

Detailed below is the proposed methodology for collecting each of these data items. Each item is described, and the proposed method of collecting that item is presented. Some aspects of this methodology were later modified as described in the following chapter (Data Collection - Execution and Problems).

4.3 Wait Time

Several issues were considered for measuring waiting time. First, there was the "type" of wait to measure, which implied the "type" of stops to observe. Also, several definitions of wait time were possible. Past researchers give guidance here. Finally the actual measurement of time required consideration. Each of these aspects are discussed in the following sections.

4.3.1 Type of Waits

Many past researchers gave little consideration to the type of wait being observed. However, as explained below, the type of wait can have a significant impact on the wait times measured.

For this research, only waits where passengers are free to choose their arrival times within the bus headway are considered. This condition allows observation of waits where passengers may optimize their waits by adjusting their bus stop arrival time. An example of such a wait is a trip starting from a residential area, where the observed stop is the first stop that the passenger started the trip. This condition is violated for trips going home from work, as the passengers bus stop arrival time (and therefore their wait time) is likely constrained by their work quitting time. This "free choice" arrival time condition also rejects transfer trips which arrive at the observed stop by bus. In this case wait times are controlled by the arrival time of the bus that passengers alighted. The effect of transfers was recognized by Smith, et al (1978), Seddon and Day (1974), and Lam and Morrall (1982).

The type of wait desired also imposes some restrictions on the type of stop to be observed, as detailed below.

4.3.2 Type of Stop

In order to observe the type of wait discussed above, it would be necessary to restrict observations to

residential areas and to stops where transfers would be unlikely. Several other considerations would be required. Both Seddon and Day (1974) and Jolliffe and Hutchinson (1975) give good guidance for selecting stops to observe. They suggest stops with the following characteristics:

1. service by a single route
2. high passenger usage
3. "open space".

Service by a single route would be required so that the headway that a passenger faces would be known. One could ask passengers which buses they could catch, but it would not be possible to ask passengers with zero waits. As an extension to this rule, it would be possible to observe stops with multiple routes if these routes have either completely common or completely uncommon downstream destinations. For routes with completely common downstream destinations, passengers can catch the first available bus. The headway they face would be the combined headway of all routes at that stop. For routes with completely uncommon downstream destinations, the headway that passengers face would be the headway of the bus caught.

Stops with high (but manageble) passenger usage would be desired so that the amount of time collecting data would be minimized.

The "open space" characteristic would be desired so that passengers wait in clear view. Seddon and Day (1974) found that passengers may hide waits by standing at a

corner, waiting for one of two routes, or by walking along the route until they either saw a bus approaching or felt that it was due to arrive. Jackson (1977) found that passengers may wait inside nearby apartments. In Edmonton, it has been observed that some passengers wait inside apartments, especially if they have a vantage point to observe approaching buses well in advance. The "open space" characteristic would help ensure the total passenger wait would be measured, not just the wait at the stop.

In addition to the above guidelines, it was decided to select stops where the service frequency would be one bus every 15 minutes. It was not necessary to collect data for several headways to accomplish the research objective. Also, past research showed that passenger arrivals may be random up to a maximum headway of 13 minutes. This implies that there would be no incentive to optimize waits, and therefore trip purpose, experience catching the bus, and schedule knowledge may be irrelevant explanatory variables under such conditions. A 15 minute headway is a common headway for Edmonton Transit and would imply good passenger usage.

4.3.3 Definitions of Wait Time

Measuring wait time requires observation of passenger arrival times and bus arrival times. Thus definitions for bus and passenger arrival times would be required. A surprising amount of choice exists for such definitions.

Chapman, et al (1976) give a good discussion on three possible measures of wait time:

1. from passenger arrival time to bus arrival time
2. from passenger arrival time to passenger boarding time
3. from passenger arrival time to bus departure time

They note that negative waits are possible with the first definition, unless these are defined as zero.

Chapman, et al (1976) state that the second definition may be closest to perceived wait time, since until the bus is actually boarded the passenger is not sure that there will be no need to wait for the next bus. However, in Edmonton it is rare that passengers are passed-up. Also, from a practical perspective, an observer must remember which passenger belongs to each recorded arrival time. This can be confusing if several passengers board a bus. Also, it would be difficult to simultaneously record precise boarding times for each passenger and correctly match these boarding times to a recorded arrival time. In Edmonton the usual time difference between the first and last passenger boarding is small.

Chapman, et al (1976) state that the third definition of wait time can be related to the headways between buses, as the number of passengers waiting is a function of time since the previous bus departure. This relation is likely true only for close interval services.

Other researchers also discuss how to measure wait time. Seddon and Day (1974) measured wait times using both bus arrival and bus departure times. They found that their regressions of wait time on headways gave better fits when using bus departure times. Lam and Morrall (1982) also used bus departure times to calculate wait times.

Based on the experiences of past researchers, passenger wait time for this research is defined as the difference between bus departure time and passenger arrival time. Definitions for each of these components are given below.

4.3.3.1 Definition of Bus Departure Time

Bus departure time would be defined as the point in time when either the bus doors close (rear or front, whichever is last), or the bus reaches the "Transit Zone" sign (if no passengers are present). Obviously, if no passengers are present then no waits are measured. However, such data could be used to help verify bus schedule adherence.

4.3.3.2 Definition of Passenger Arrival Time

The second component of wait time, the passenger arrival time, is more difficult to define. This is due to the lack of a sharp, definite event in time that defines passenger arrivals as they approach a stop. In the preliminary study conducted in June/July 1987, passenger arrival time was defined as the point in time when the passenger stops walking. However, some

passengers slowed their pace as they neared the stop. Lam and Morrall (1982) also noted this behavior. Other passengers would slowly proceed past the stop then turn around or would pace. It was obvious that these passengers had no chance of missing the bus, yet by the definition they had not yet arrived. Thus the definition needed broadening.

This research defines passenger arrival time as the point in time that a passenger is in the "vicinity" of the stop. "Vicinity" here means that the passenger is on the same corner as the stop and cannot miss the bus at his current walking speed. Although this definition required judgement on the observer's part, it was felt that it more closely followed the passengers' perspective of arrival, i.e when they feel that there is no chance of missing the bus.

4.4 Measuring Time

Measurement of bus departure and passenger arrival times would require a watch calibrated to a standard time. Edmonton Transit usually broadcasts the time once every hour on the hour over their bus radio system. This time was used as the standard, as it would help to estimate bus schedule adherence. The calibration procedure would be to periodically listen to the broadcast of Transit time on buses laying over at the University Transit Terminal. To guard against "drift" of the observer's watch, it would be

calibrated to another clock at the observer's residence.

4.5 Weather Data

Since the objective of collecting weather data was to determine if passenger arrival behavior changes with weather, it was felt that passenger behavior may provide clues as to the type of weather observed. If passengers were to shift from one foot to another, or to use the passenger shelter more than usual, or to mention that it feels cold, then such behavior could help classify the weather observed.

Additional weather data would include air temperatures from broadcasts on local radio stations immediately prior to the observation period. Also, any precipitation and wind would be noted.

The advantage of using passenger behavior rather than objectively measured values to classify weather is that similar weather conditions may not produce similar passenger behaviors. For example, a 5°C temperature on a winter day may be very comfortable for passengers, and thus may be a "good" weather day. However, a 5°C temperature day on a summer day may be highly uncomfortable and thus passengers may make special efforts either to minimize their waits or to ensure that they will not miss the bus. A "bad" weather day would result.

The main disadvantage of such a method is its subjective nature. The analysis of the data may give some indication as to the method's validity.

In the interests of simplicity, weather would be classified as "good" or "bad" only. Weather classification would take place immediately after the observation period.

Observations would not be taken on days where the weather was so poor that buses would be forced off schedule. Bus arrivals would then tend to be unpredictable, and passenger experience or schedule knowledge would be useless.

4.6 Group Arrivals

A group arrival would be defined as a simultaneous arrival of two or more person walking together and seeming to know one another. Although there was little known effect of group arrivals on wait time, it was thought that there may be some impacts. Passengers that arrived in groups would be noted during data collection. They were assigned common arrival times.

4.7 Passenger Data - Use of Interviews

Collecting passengers' trip purpose, schedule knowledge, and experience would require interaction with passengers. A good practical method to obtain the required passenger data was to interview passengers at bus stops. A post-back questionaire could have been used, but Hunt (1984) states that interviews usually have higher response rates and that the interviewer can clarify questions. Also, post back questionaires have higher monetary costs.

Hunt (1984) also stated that test interviews can be conducted to help design the exact wording of questions. This study's questions were based on the preliminary study conducted in June/July 1987. Interviews also present an opportunity for good public relations. A "Thank-you" letter would be given to participants, aiding future Transportation studies.

Interviews were also used by Jackson (1977) to classify passenger arrivals as random or non-random. He felt that his interviews were successful in this respect.

Thus the interview would be used as the means of obtaining passenger data. However, the decision to use the interview format to collect the data would raise two concerns:

1. Possible mental harm to passengers caused by the interview process
2. Obtrusive observations - i.e. the interviewer's presence affecting the data he would be measuring.

These concerns are each addressed in the following two sections.

4.7.1 Mental Harm Concerns

Because interviews would require the researcher to initiate contact with members of the public, University of Alberta regulations required that an Ethics Review Committee approve the intended interview. These regulations required that the passengers understand that they are being used for

research purposes. Thus the interviewer commenced each interview by stating:

> "Hi! I'm a university student conducting research on the time people wait for buses, and I was wondering if you could help me out by answering four non-personal questions?"

The Department of Civil Engineering Ethics Review Committee required that the interviewer carry his student identification card while conducting interviews. Futhermore, each interviewed passenger would receive a "Thank-you" letter. It would contain the supervisor's name, mailing address, and phone number. This would provide members of the public an opportunity to comment on the interviewer's conduct and on the interview itself. Figure 4.1 shows the first version of the "Thank-you" letter.

To further justify his presence at bus stops, the interviewer would carry a generic letter from his supervisor. This letter would explain the interviewer's purpose, and give a contact address and phone number. A copy of this letter is shown in Figure 4.2. It would be intended for persistent members of the public who doubted the interviewer's presence, and for police officers who may have been called to the stop by members of the public.

4.7.2 Obtrusive Observation Concerns

Obstrusive observations were of concern to other researchers. Hill (1986) observed the route choice of

Dear Passenger,

Thank-you for participating in this research. If you have any questions or concerns regarding this study, you may contact:

Marcel Huculak (Interviewer)
Room 219J
Civil Engineering Building
University of Alberta
EDMONTON, Alberta
T6G 2G7
ph. 432-2795

Professor J.J. Bakker (Supervisor)
Department of Civil Engineering
Civil Engineering Building
University of Alberta
EDMONTON, Alberta
T6G 2G7
ph. 432-5112

Yours sincerely,

Marcel Huculak

Figure 4.1 A copy of the "Thank-you" Letter, First Version.

University of Alberta
Edmonton
Canada T6G 2G7

Department of Civil Engineering
220 Civil Electrical Engineering Building
Telephone (403) 432-4235

Oct. 29/88

To whom it may concern:

The bearer of this letter, Mr. Marcel Huculak, is collecting data concerning the time bus passengers wait for buses. These data are for research being conducted in the Department of Civil Engineering at the University of Alberta. These data do not compromise the privacy of the bus passengers.

If you have any concerns or questions, please call me at 432-5112.

Thank-you.

Sincerely,

J.J. Bakker
Professor of Civil Engineering

Figure 4.2 Generic letter to legitimize interviewer's presence.

elementary school children walking home from school by following them home. He used a rule that if a child were to turn around and see him on two occassions, then that observation would be discarded.

Monnette, et al (1986) give an excellent discussion on research observation techniques. They state that, with respect to validity of data, the Researcher-Participant relation has two critical issues:

1. the extent to which the observer changes the setting that is being observed
2. the extent to which people should be informed that they are being used for research purposes.

Issue number two was addressed in the previous section. Clearly the research method would be entirely up-front and open to the passengers. It is issue number one that would be important here.

Because of the observer's presence, passengers may try to optimize their arrival times so as to appear more rational in the eyes of the observer. Bus operators may also become more conscious of their arrival times if they know that they are being observed.

Thus some strategies would be introduced to help minimize the observer's impact on the arrival time data. First, since passengers cannot predict the observer's first appearance, their arrival behavior would not be affected by the observer's first presence. Thus stops would only be observed once so that the possibility of observing a

passenger more than once would be minimized.

Second, the observation period at a stop would be limited to the round trip time of buses on that route. Thus, drivers would only see the observer no more than twice at the observed stop - once in the observed direction and once in the opposite direction (for stops not on one way route loops). This strategy is likely adequate. If a driver sees the observer before going through the observed stop, he would likely think that the observer is a passenger. When driving through the observed stop, the driver may notice the observer recording data, and that the observer never boarded. But by this point it is too late for the driver to alter his arrival time.

Third, stops on the same route would not be observed on consecutive days. This would make it more difficult for drivers and passengers to predict the observer's presence.

Despite these strategies it is still possible for drivers on a route to fore-warn other drivers on that route of the observer's presence. It would be impossible to prove or prevent this, but some data from the preliminary study (June/July 1987) discredits this possibility.

During the preliminary study an observer stationed himself across the street from a stop (Route 18 westbound at 118 Avenue - 38 Street) for nineteen consecutive weekdays. The observer was in plain view (i.e. he was not in a car). Although he tried to diguise the fact that he was collecting bus arrival data, it was clear that at least one driver grew

suspicious of the observer's continued presence.

Notwithstanding this obtrusive observation method, bus departure time distributions were constructed from the data collected. Two distributions for the same bus runs (observed twice per day at the observed stop) are shown in Figure 4.3. It is likely that only one or two drivers who regularly drive this route are responsible for each bus run. It is clear that Set "A" of drivers is highly unreliable compared to Set "B" of drivers. It is likely that this difference is due to the drivers alone. Traffic conditions are similar for both bus runs, and because they were both observed twice per day, differences due to one bus possibly originating from the garage should not be present. Further, some of Set "A" drivers' arrival times fail to meet Edmonton Transit standards, and would be subject to disciplinary action. Monnette, et al (1986) state that if people behave strangely (for example, do something illegal), one may assume that they are not affected by the observer's presence. Therefore this particular observation technique, which was highly obtrusive compared to the present technique, was still effective for at least some observations.

Therefore, this research assumes that the observer's presence does not alter the arrival time behavior of passengers and drivers. It is believed that the proposed strategies to minimize the impact of the observer's presence on passengers and drivers will validate this assumption. During data collection, the observer would note events that

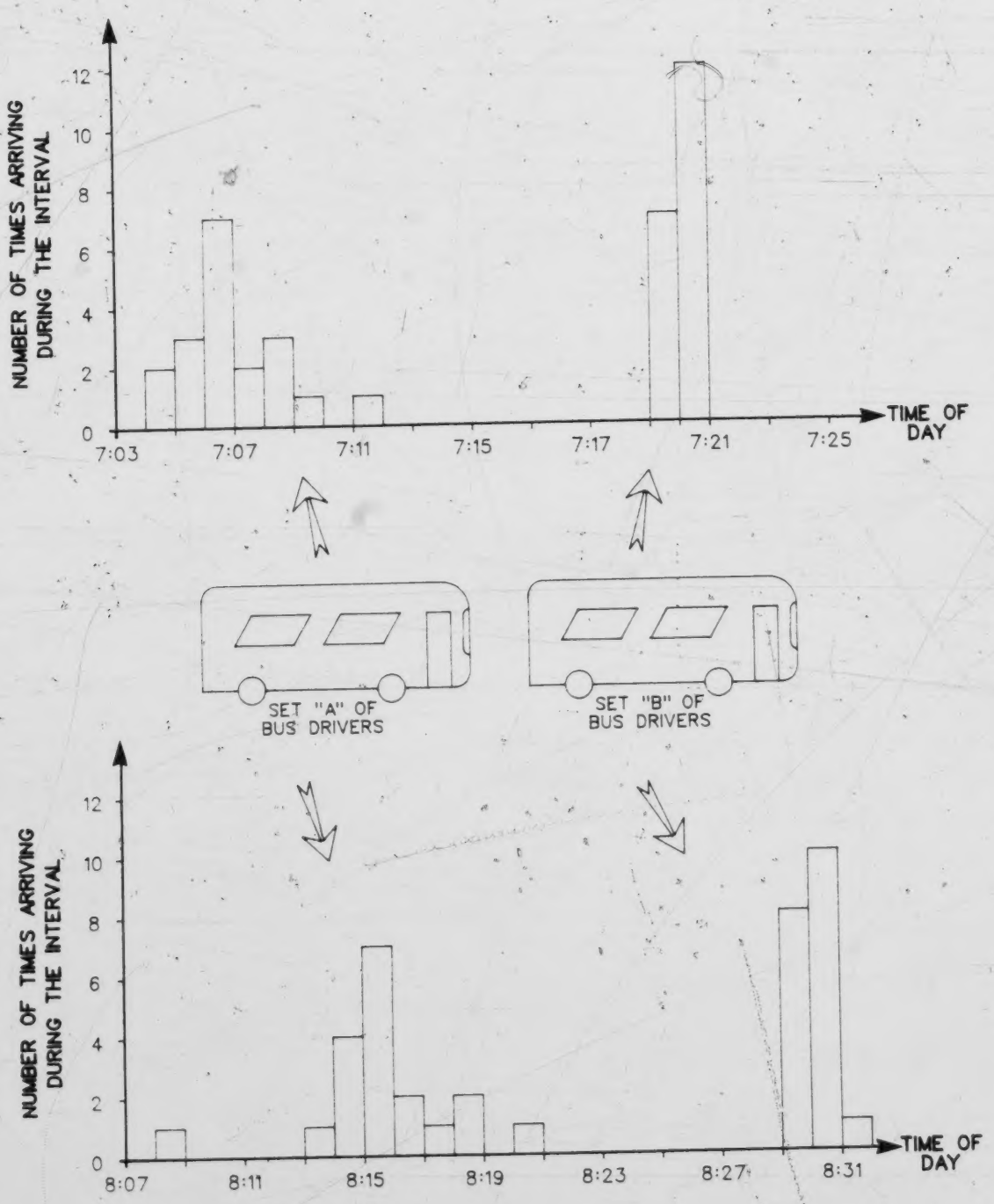


Figure 4.3 Bus departure distributions for two sets of drivers, from the preliminary study (Route 18 westbound at 118 Avenue - 38 Street.

indicate the level of success of the observation method.

4.8 Design of Interview Questions

The original design of each interview question is presented in this section. General considerations are discussed first. Then each interview question is presented, and the rational behind each question is explained. Wording for the first three interview questions was based on the preliminary study of June/July 1987.

4.8.1 General Interview Considerations

Passenger interviews would be required to determine trip purpose, experience catching the bus, and schedule knowledge. To determine each of these precisely would require many questions. However, there are practical constraints which limit the depth of questioning.

One constraint is that there would be a need to interview as many passengers as possible. If the interview were too long, many passengers could not be interviewed before the bus arrived.

A longer interview would introduce a heavier sampling bias. The proportion of interviewed passengers with short waits would be less than those with long waits. Jackson (1977) found such a interview sampling bias in his data despite his interview having only two questions. The preliminary study showed that the passenger arrival rate is greatest in the last five minutes of the headway. If this

arrival rate exceeds the rate at which passengers are interviewed then a queue of non-interviewed passengers would form. Once the bus arrives this potential pool of data would be lost.

Thus the interview design would become a trade-off of level of detail versus the number of interviews and the lengths of waits associated with interview data. The interview would be kept as short as possible. It would then not be possible to precisely determine the information required in the interview. Therefore, the interview responses would become surrogates for the true values of passenger trip purpose, experience, and schedule knowledge.

4.8.2 Interview Question 1, Trip Purpose

The trip purpose question would be the first interview question. It would be worded as:

> "What is the purpose of your trip? (What are you going to do?)"

The bracketed portion would be optional. It would be asked only to clarify the question for puzzled looking passengers. Response options would include "work", "school", "shopping", "recreational", and "other".

The trip purpose question appeared first on the interview for several reasons. First, it would be simple. Second, answers could be coached out of passengers with little chance of biasing the result. Coaching would promote a cooperative spirit between the interviewer and passenger.

It also would help gain a passenger's trust. Finally, the passenger's confidence would be boosted by correctly answering the question.

The level of detail provided by this question would be satisfactory. However, persons who chain trips would not be detected.

4.8.3 Interview Question 2, Experience

Interview question 2 would attempt to determine passenger experience catching the bus. It would be worded as:

"How many times did you catch the bus to make this trip at this stop last week?"

Response options would include zero through five individually and greater than five.

The underlying assumption would be that passenger frequency of use (at that stop, for that trip purpose) would be a resonable measure of their experience. Any experience gained at other stops, or from other trips purposes or passengers would not be detected. However, the degree to which such other experiences would help a passenger catch the bus at the observed stop could only be determined through additional questions.

Passengers may have experience catching the bus at the observed stop during different schedule periods or times of the day. Again, this kind of experience would be assumed irrelevant. The question thus would ask for experience "to

make this trip", assuming that different trips would be made at different times of the day.

Passenger experience would be limited to a time frame including only "last week". It would be likely easy for passengers to remember their trip behavior over the last week, as compared to a longer time period. This would represent a passenger's most recent experience and passengers who would be just learning when to catch the bus probably compiled enough experience in one week to become experienced users.

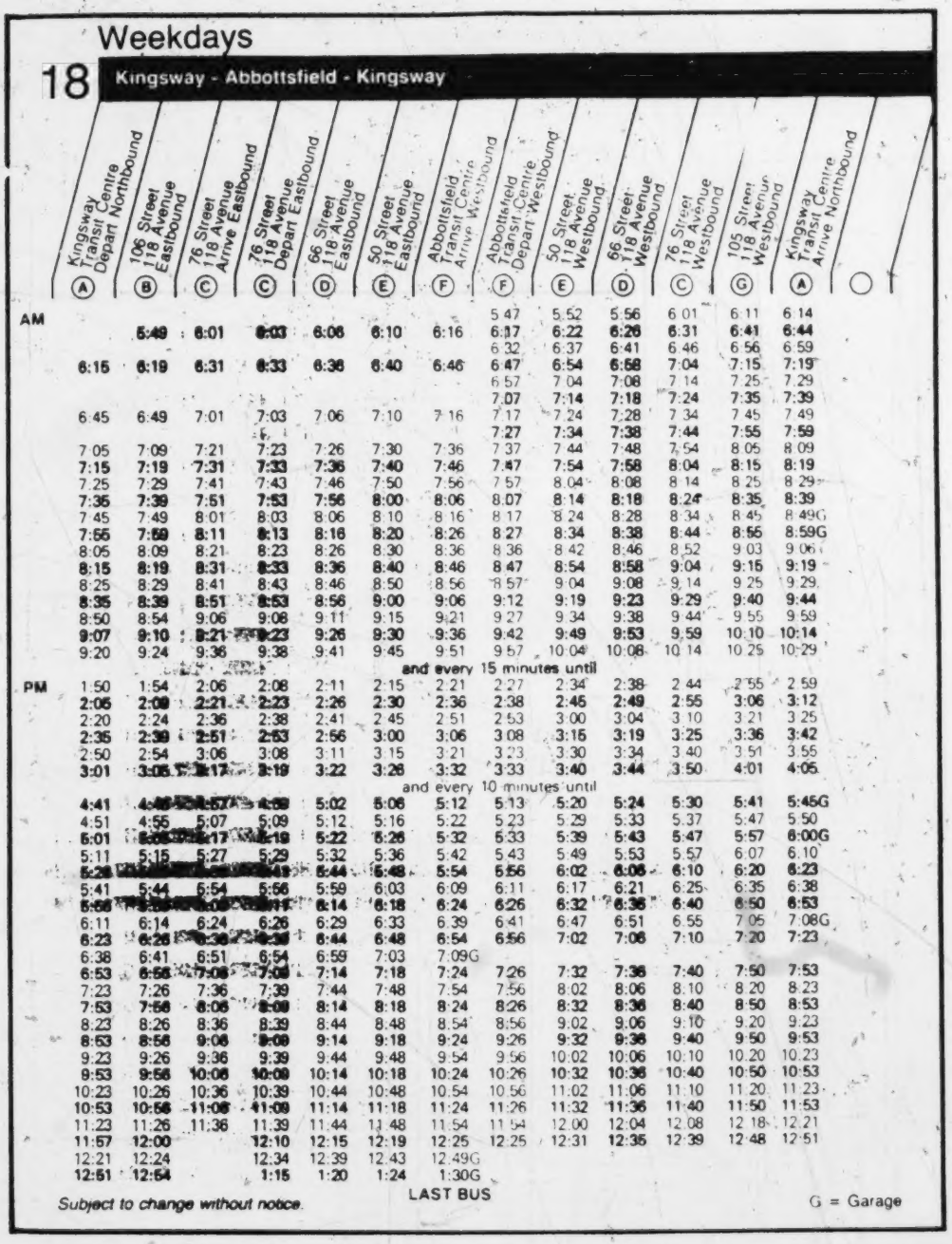
Generally, this question is more difficult than interview question 1 as some memory recall would be required. But passengers would likely provide a response to their satisfaction.

4.8.4 Interview Question 3, Schedule Knowledge

This question would determine a passenger's schedule knowledge. It would be worded as:

"What time does this bus depart (the nearest upstream timing point)?"

The bracketed portion would quote the column heading description of the nearest upstream timing point printed in the publically available route schedule pamphlets. An example of Edmonton Transit's published schedule information is shown in Figure 4.5. In Edmonton Transit's published schedule information, this would be the best schedule information a passenger may obtain. Bus arrival times are



Weekdays

18 Kingsway - Abbottsfield - Kingsway

	Kingsway Transit Centre Depart Northbound (A)	106 Street 118 Avenue Eastbound (B)	76 Street 118 Avenue Arrive Eastbound (C)	76 Street 118 Avenue Depart Eastbound (C)	66 Street 118 Avenue Eastbound (D)	50 Street 118 Avenue Eastbound (E)	Abbottsfield Transit Centre Arrive Westbound (F)	Abbottsfield Transit Centre Depart Westbound (F)	50 Street 118 Avenue Westbound (E)	66 Street 118 Avenue Westbound (D)	76 Street 118 Avenue Westbound (C)	105 Street 118 Avenue Westbound (G)	Kingsway Transit Centre Arrive Northbound (A)	○
AM								5:47	5:52	5:56	6:01	6:11	6:14	
		5:49	6:01	6:03	6:08	6:10	6:16	6:17	6:22	6:26	6:31	6:41	6:44	
								6:32	6:37	6:41	6:46	6:56	6:59	
	6:15	6:19	6:31	6:33	6:38	6:40	6:46	6:47	6:54	6:58	7:04	7:15	7:19	
								6:57	7:04	7:08	7:14	7:25	7:29	
								7:07	7:14	7:18	7:24	7:35	7:39	
	6:45	6:49	7:01	7:03	7:06	7:10	7:16	7:17	7:24	7:28	7:34	7:45	7:49	
								7:27	7:34	7:38	7:44	7:55	7:59	
	7:05	7:09	7:21	7:23	7:26	7:30	7:36	7:37	7:44	7:48	7:54	8:05	8:09	
	7:15	7:19	7:31	7:33	7:36	7:40	7:46	7:47	7:54	7:58	8:04	8:15	8:19	
	7:25	7:29	7:41	7:43	7:46	7:50	7:56	7:57	8:04	8:08	8:14	8:25	8:29	
	7:35	7:39	7:51	7:53	7:56	8:00	8:06	8:07	8:14	8:18	8:24	8:35	8:39	
	7:45	7:49	8:01	8:03	8:06	8:10	8:16	8:17	8:24	8:28	8:34	8:45	8:49G	
	7:55	7:59	8:11	8:13	8:16	8:20	8:26	8:27	8:34	8:38	8:44	8:55	8:59G	
	8:05	8:09	8:21	8:23	8:26	8:30	8:36	8:36	8:42	8:46	8:52	9:03	9:06	
	8:15	8:19	8:31	8:33	8:36	8:40	8:46	8:47	8:54	8:58	9:04	9:15	9:19	
	8:25	8:29	8:41	8:43	8:46	8:50	8:56	8:57	9:04	9:08	9:14	9:25	9:29	
	8:35	8:39	8:51	8:53	8:56	9:00	9:06	9:12	9:19	9:23	9:29	9:40	9:44	
	8:50	8:54	9:06	9:08	9:11	9:15	9:21	9:27	9:34	9:38	9:44	9:55	9:59	
	9:07	9:10	9:21	9:23	9:26	9:30	9:36	9:42	9:49	9:53	9:59	10:10	10:14	
	9:20	9:24	9:36	9:38	9:41	9:45	9:51	9:57	10:04	10:08	10:14	10:25	10:29	
							and every 15 minutes until							
PM	1:50	1:54	2:06	2:08	2:11	2:15	2:21	2:27	2:34	2:38	2:44	2:55	2:59	
	2:06	2:09	2:21	2:23	2:26	2:30	2:36	2:38	2:45	2:49	2:55	3:06	3:12	
	2:20	2:24	2:36	2:38	2:41	2:45	2:51	2:53	3:00	3:04	3:10	3:21	3:25	
	2:35	2:39	2:51	2:53	2:56	3:00	3:06	3:08	3:15	3:19	3:25	3:36	3:42	
	2:50	2:54	3:06	3:08	3:11	3:15	3:21	3:23	3:30	3:34	3:40	3:51	3:55	
	3:01	3:05	3:17	3:19	3:22	3:26	3:32	3:33	3:40	3:44	3:50	4:01	4:05	
							and every 10 minutes until							
	4:41	4:45	4:57	4:59	5:02	5:06	5:12	5:13	5:20	5:24	5:30	5:41	5:45G	
	4:51	4:55	5:07	5:09	5:12	5:16	5:22	5:23	5:29	5:33	5:37	5:47	5:50	
	5:01	5:05	5:17	5:19	5:22	5:26	5:32	5:33	5:39	5:43	5:47	5:57	6:00G	
	5:11	5:15	5:27	5:29	5:32	5:36	5:42	5:43	5:49	5:53	5:57	6:07	6:10	
	5:21	5:25	5:37	5:39	5:42	5:46	5:52	5:53	5:59	6:03	6:07	6:17	6:20	
	5:41	5:44	5:54	5:56	5:59	6:03	6:09	6:11	6:17	6:21	6:25	6:35	6:38	
	5:56	5:59	6:09	6:11	6:14	6:18	6:24	6:26	6:32	6:36	6:40	6:50	6:53	
	6:11	6:14	6:24	6:26	6:29	6:33	6:39	6:41	6:47	6:51	6:55	7:05	7:08G	
	6:23	6:26	6:36	6:38	6:41	6:48	6:54	6:56	7:02	7:06	7:10	7:20	7:23	
	6:38	6:41	6:51	6:54	6:59	7:03	7:09G							
	6:53	6:56	7:06	7:09	7:14	7:18	7:24	7:26	7:32	7:36	7:40	7:50	7:53	
	7:23	7:26	7:36	7:39	7:44	7:48	7:54	7:56	8:02	8:06	8:10	8:20	8:23	
	7:53	7:56	8:06	8:09	8:14	8:18	8:24	8:26	8:32	8:36	8:40	8:50	8:53	
	8:23	8:26	8:36	8:39	8:44	8:48	8:54	8:56	9:02	9:06	9:10	9:20	9:23	
	8:53	8:56	9:06	9:09	9:14	9:18	9:24	9:26	9:32	9:36	9:40	9:50	9:53	
	9:23	9:26	9:36	9:39	9:44	9:48	9:54	9:56	10:02	10:06	10:10	10:20	10:23	
	9:53	9:56	10:06	10:09	10:14	10:18	10:24	10:26	10:32	10:36	10:40	10:50	10:53	
	10:23	10:26	10:36	10:39	10:44	10:48	10:54	10:56	11:02	11:06	11:10	11:20	11:23	
	10:53	10:56	11:06	11:09	11:14	11:18	11:24	11:26	11:32	11:36	11:40	11:50	11:53	
	11:23	11:26	11:36	11:39	11:44	11:48	11:54	11:54	12:00	12:04	12:08	12:18	12:21	
	11:57	12:00		12:10	12:15	12:19	12:25	12:25	12:31	12:35	12:39	12:48	12:51	
	12:21	12:24		12:34	12:39	12:43	12:49G							
	12:51	12:54		1:15	1:20	1:24	1:30G							
							LAST BUS							

Subject to change without notice.

G = Garage

Figure 4.4 Example of Edmonton Transit's published schedule information.

not available for most stops in Edmonton.

It would be possible that passengers may have other useful schedule knowledge. For example, a downstream timing point may be closer. However, buses may arrive early at this timing point and then lay over. Thus extrapolating bus stop arrival times from this information would be more difficult.

This interview question is the most difficult as it requires a specific answer. Passengers may suffer the embarassment of not knowing the answer. Since it may be a discouraging question, it would be placed near the end of the interview, after other data has already been extracted.

4.8.5 Interview Question 4, Method of Payment

Interview question 4 would confirm the passenger's experience, and check the validity of the reponses provided. It would be worded as:

"How will you pay for your trip?"

Response options included "pass", "cash", "ticket", or "transfer".

Passengers claiming frequent use (from interview question 2) should respond "pass", while infrequent users should respond "cash" or "ticket". "Transfer" would be included as a response to help prevent the possibility of including such passengers in the data. Responses inconsistent with the experience question would negate interview results for that passenger.

This question would be included because the experience interview question may be the least reliable, as passengers may not be precise. This question is short, and would not significantly lengthen the interview.

Interview question 4 ends the interview on a positive note. Passengers can be happy that they would provide another response to their satisfaction.

4.9 Data Collection Method - Summary

The end result of the preceeding discussions was the data collection form, shown in Figure 4.5. This form was used for recording arrival time data and interview data.

To summarize, the proposed data collection method was to first find stops which satisfy the stop selection criterion. At these stops the data would be collected. First the objective weather data would be noted, then arrival time data and interview data would be collected after the departure of the first observed bus. After the last bus departs the stop, notes regarding the weather behavior of passengers are made, and any other relevant events could be recorded. After enough data were collected, the in field data collection experiences could be summarized and data analysis could commence.

DATE:_____ DAY:_____ ROUTE:_____

LOCATION:_____

ARRIVAL TIME:_____ BUS ARRIVAL TIME:_____

1. What is the purpose of your trip? (What are you going to do?)

__WORK __SCHOOL __SHOPPING __RECREATION __OTHER_____
__JR HIGH
__HIGH SCHOOL
__UNIVERSITY OR COLLEGE

2. How many times did you catch the bus to make this trip at this stop last week?

__1 __2 __3 __4 __5 __5+_____

3. Do you know what time this bus is scheduled to depart _____?

__NO __YES; WHAT IS THAT TIME?_____

4. How will you pay for this trip?

__CASH __PASS __TICKET __TRANSFER

ARRIVAL TIME:_____ BUS ARRIVAL TIME:_____

1. What is the purpose of your trip? (What are you going to do?)

__WORK __SCHOOL __SHOPPING __RECREATION __OTHER_____
__JR HIGH
__HIGH SCHOOL
__UNIVERSITY OR COLLEGE

2. How many times did you catch the bus to make this trip at this stop last week?

1 2 __3 __4 5 5+

3. Do you know what time this bus is scheduled to depart _____?

__NO __YES; WHAT IS THAT TIME?_____

4. How will you pay for this trip?

__CASH __PASS __TICKET __TRANSFER

Figure 4.5 Data collection form, initial version.

5. Data Collection - Execution and Problems

The pratical execution of the proposed data collection is described in the following sections. Variations from the intended data collection methodology and problems encountered are detailed. These variations and problems impact the data analysis, and provide some guidelines for similar future research.

5.1 Background Information

The data were collected on Saturdays, Mondays, and Tuesdays, beginning on Saturday October 29, 1988 and ending on Tuesday, November 30, 1988. Most data were obtained in the AM hours, especially the AM peak (06:00 to 08:00). The remainder of the data were collected in the early afternoon.

Only one observer/interviewer (the author) was used. He had been a frequent user of Edmonton Transit from September 1978 to July 1988. Approximately 230 wait times were observed and 160 interviews were conducted at 18 stops on seven routes.

5.2 Bus Stop Selection

Before any data could be collected, bus stops which met the bus stop criterion were sought. To start, an Edmonton Transit network bus route map was reviewed. All route segments with a 15 minute service interval in a residential area during either the AM Peak or Midday Schedule Period were identified. Then site investigations along these route

segments identified suitable stops, usually close to higher density housing

The stops actually used in the study are listed in Table 5.1. Given are the location of the surveyed stop, the direction of the route surveyed, the date and time of the survey, the number of wait times recorded, and the number of interviews completed for each stop. Their locations are shown on copies of Edmonton Transit route brochure maps (Figures 5.1 through 5.7).

While most of the surveyed stops did fit the stop criterion for this research, there were some exceptions. These are discussed below.

5.2.1 Route 39, 64 Avenue - 178 Street Northbound

This stop produced the most serious problems with the intended data collection method. Because of the stop's close proximity to the one way loop at the Route's southern end (see Figure 5.6), a southbound bus on 178 Street near the observed stop becomes the next northbound bus at the observed stop.

It was observed that many passengers, especially Junior High School students (ages 12 - 15), would catch the first available bus regardless of its direction. Compounding the problem were the cool temperature (about -1 ^{o}C) and noticeable wind chill. This gave passengers more incentive to catch southbound buses, as at least they would be warm on the bus while it looped around. Two passengers who started

Table 5.1 List of Surveyed Stops.

Stop Description	Date and Time Surveyed	Waits Recorded	Interviews Completed
Route 29 SBD, 152 Ave - 118 St	Sat, Oct 29, 1100-1235	3	3
	Sat, Nov 12, 1220-1310	0	0
Route 30 NBD, 179 Ave - 95 St	Mon, Oct 31, 0640-0755	31	19
Route 18 WBD, 118 Ave - 34 St	Mon, Oct 31, 0915-1015	12	10
Route 43 EBD, 47 Ave - 106A St	Tues, Nov 1, 0555-0810	8	6
Route 5 EBD, 114 Ave - 131 St	Tues, Nov 1, 0930-1010	0	0
Route 29 WBD, 152 Ave - 114 St	Sat, Nov 5, 1005-1050	1	1
Route 39 NBD, 64 Ave - 178 St	Mon, Nov 7, 0645-0810	24	17
Route 5 WBD, 114 Ave - 124 St	Mon, Nov 7, 0850-0955	5	5
	Mon, Nov 14, 1145-1345	5	3
Route 43 EBD, 47 Ave - 106 St	Tues, Nov 8 0555-0840	26	19
Route 29 SBD, 147 Ave - 118 St	Tues, Nov 8, 1055-1125	0	0
Route 30 NBD, 174 Ave - 95 St	Mon, Nov 14, 0640-0755	31	20
Route 3 SBD, 117 Ave - 124 St	Tues, Nov 15, 0625-0740	8	4
Route 29 SBD, 145 Ave - 118 St	Tues, Nov 15, 0825-0925	6	4
Route 5 EBD, 114 Ave - Groat Rd	Sat, Nov 19, 1100-1145	0	0
Route 30 NBD, 171 Ave - 95 St	Mon, Nov 21, 0640-0755	18	12
Route 43 WBD, 47 Ave - 106 St	Tues, Nov 22, 0655-0830	17	9
Route 30 NBD, 176 Ave - 95 St	Mon, Nov 28, 0625-0755	16	10
Route 43 WBD, 47 Ave - 106A St	Tues, Nov 29, 0700-0830	17	14
		SUM = 228	SUM = 156

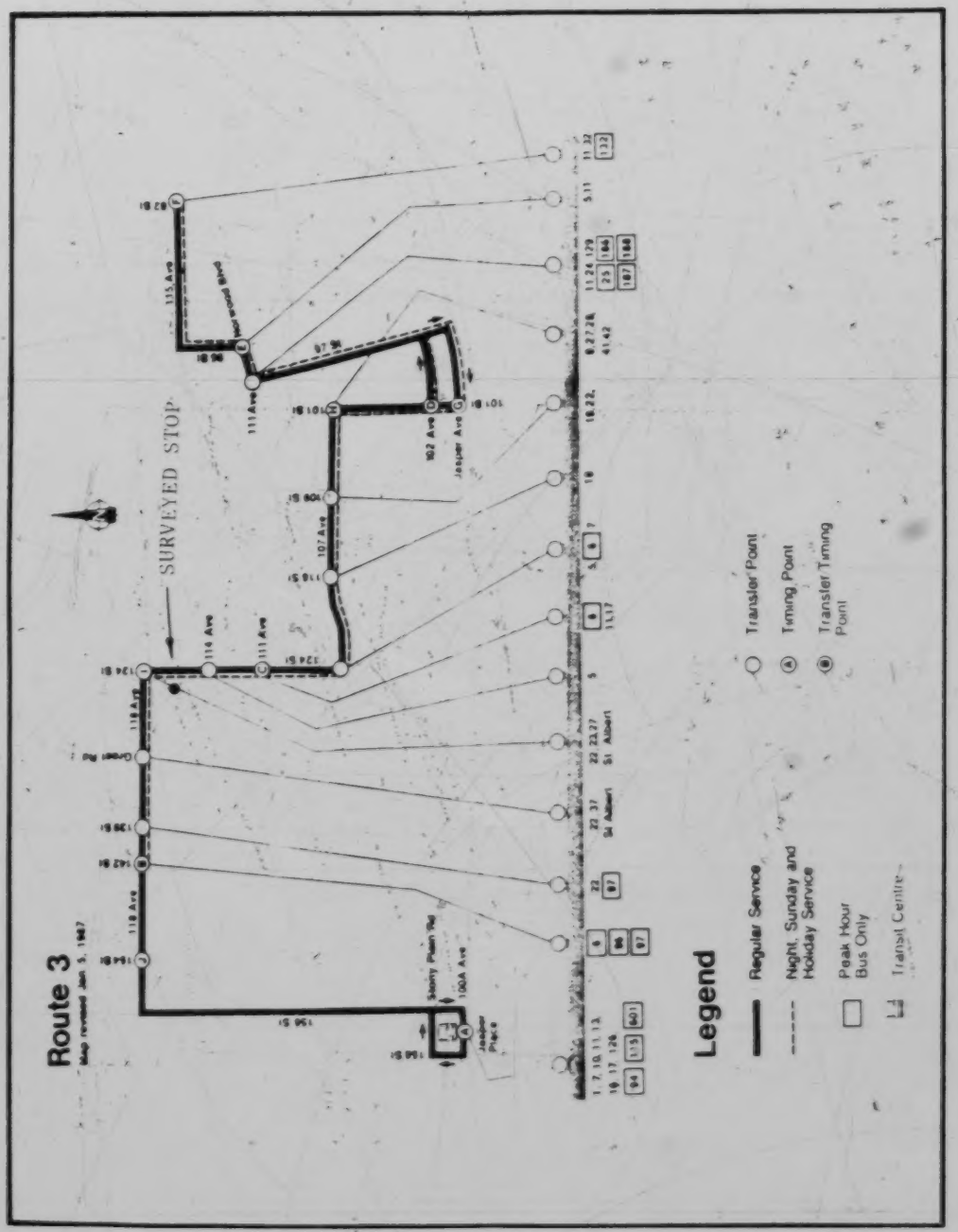


Figure 5.1 Route 3 Surveyed Stop.

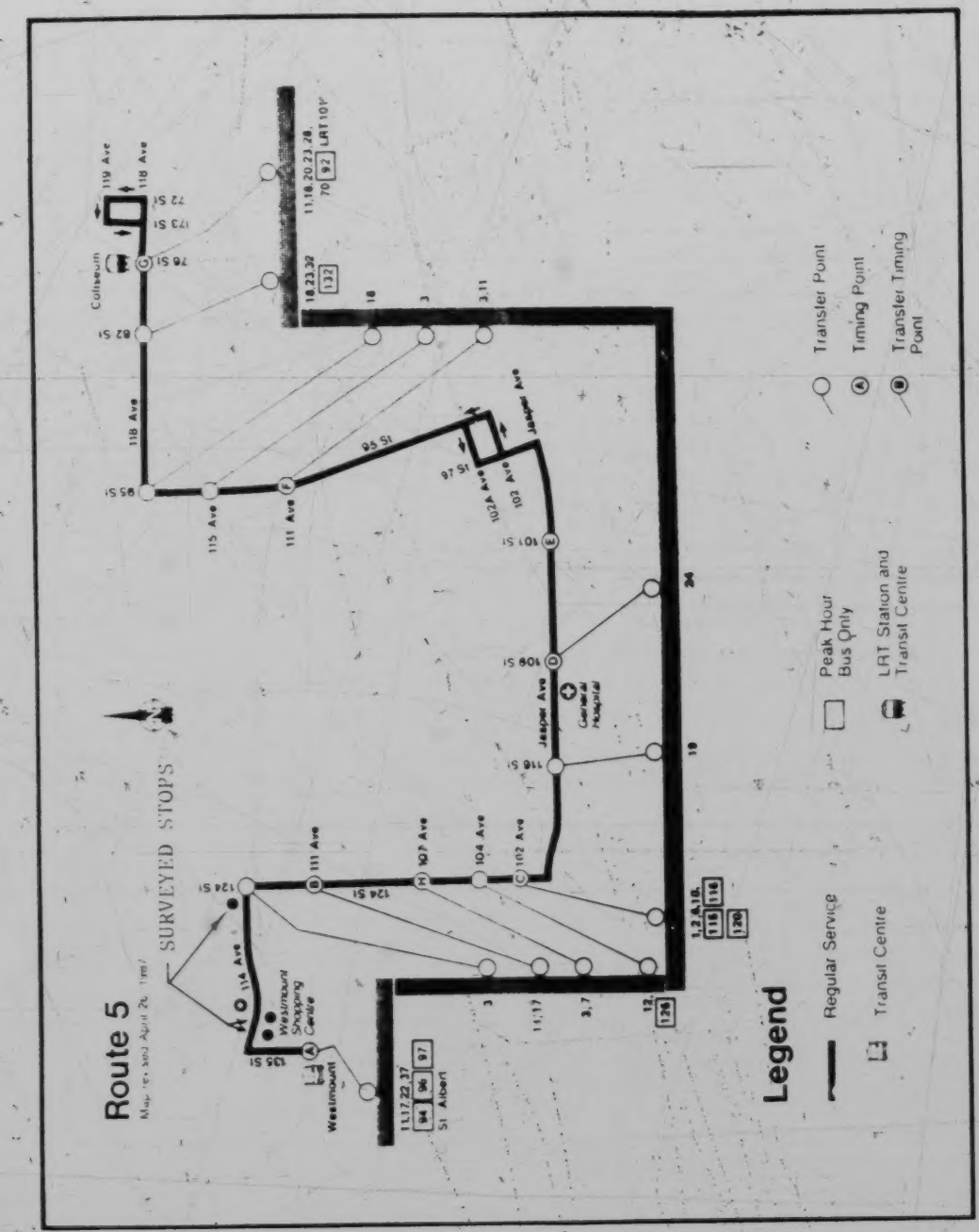


Figure 5.2 Route 5 Surveyed Stops.

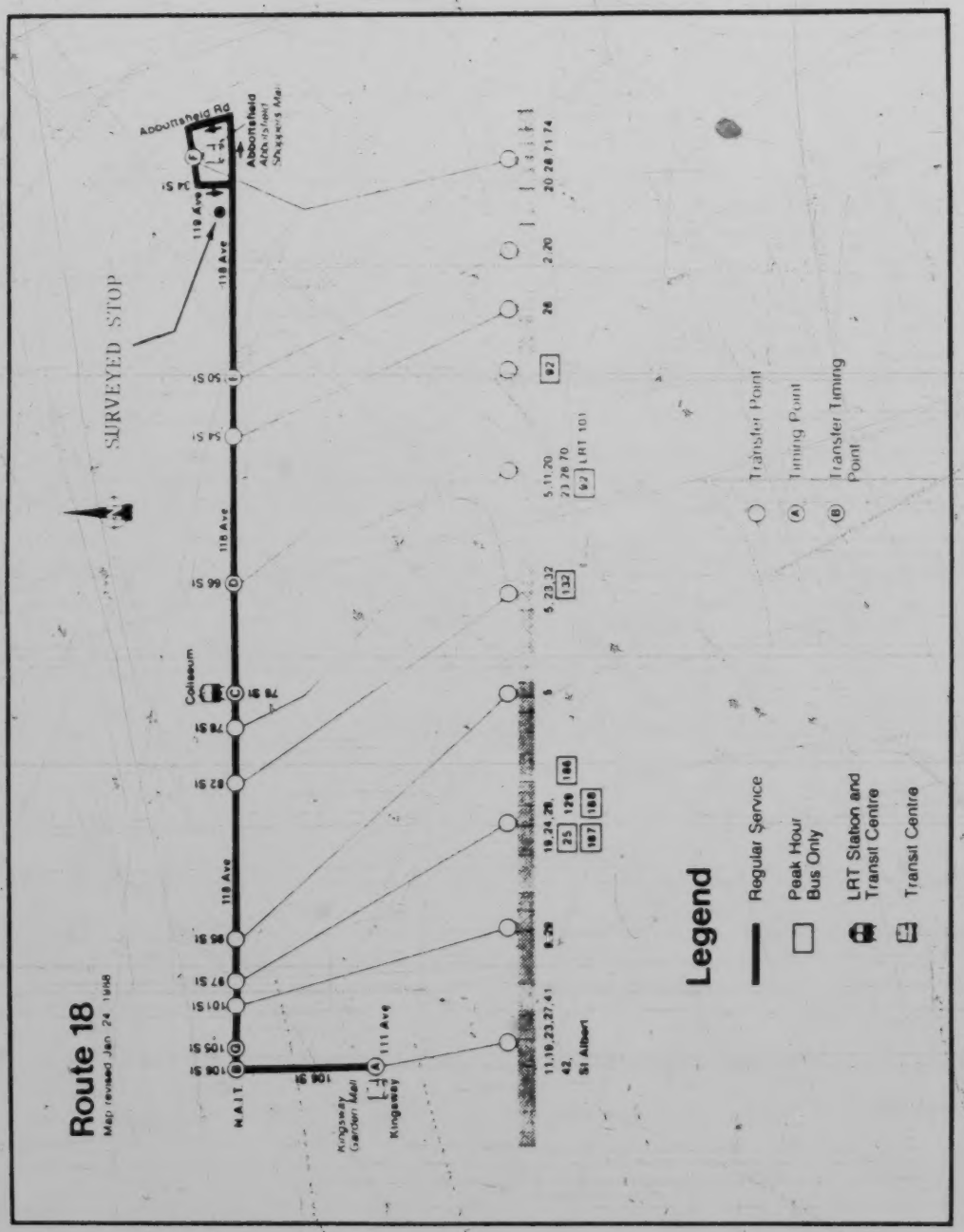


Figure 5.3 Route 18 Surveyed Stop.

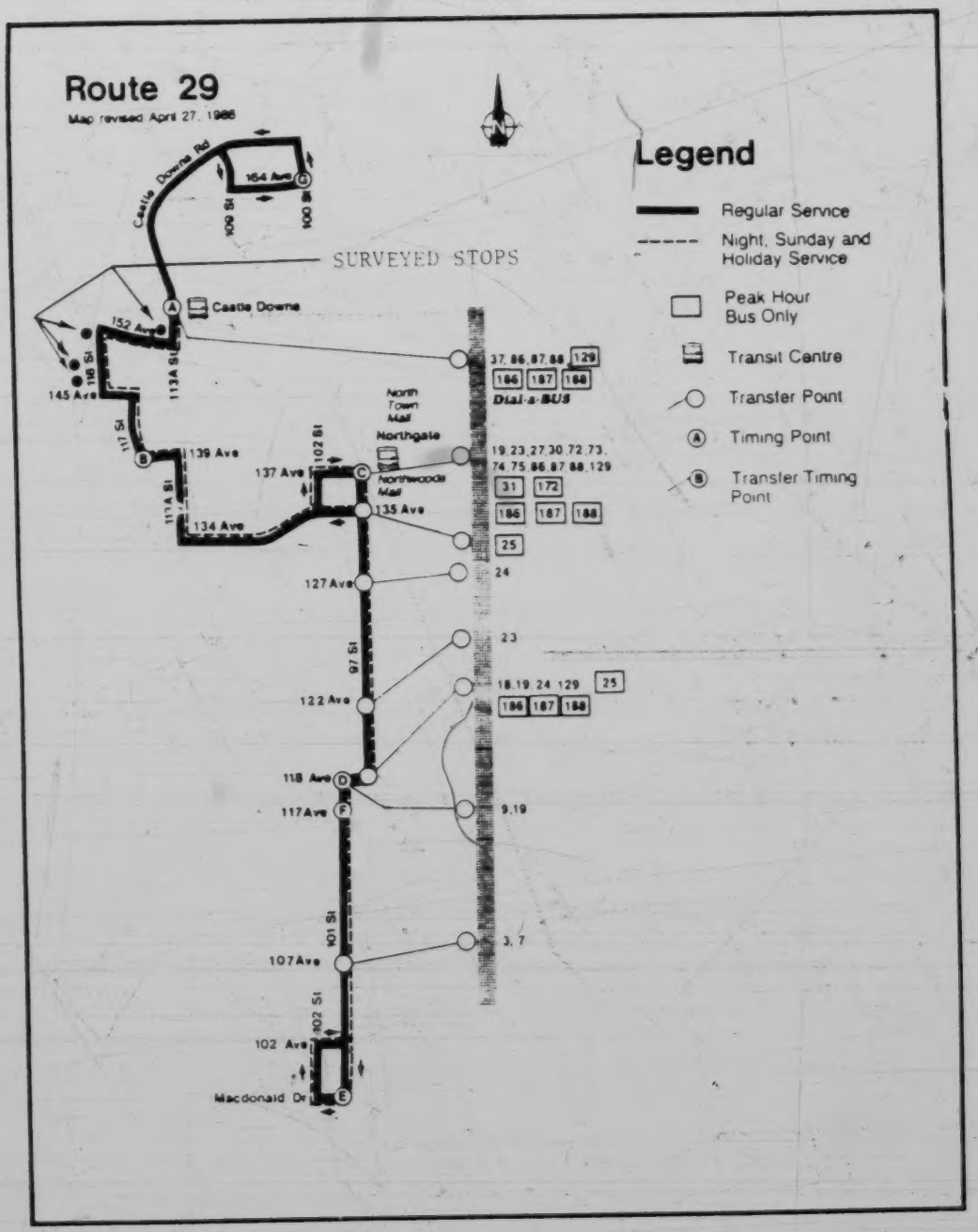


Figure 5.4 Route 29 Surveyed Stops.

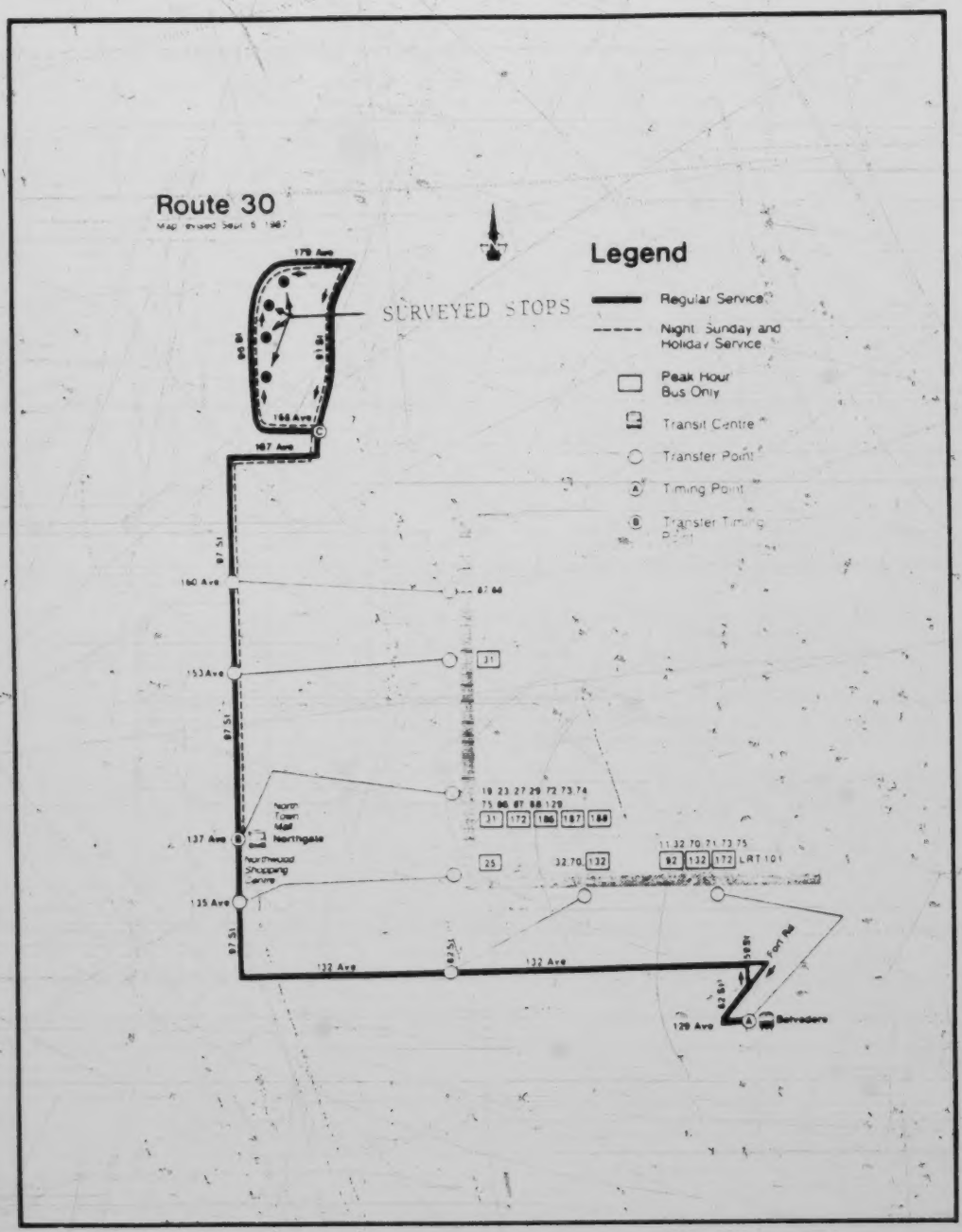


Figure 5.5 Route 30 Surveyed Stops.

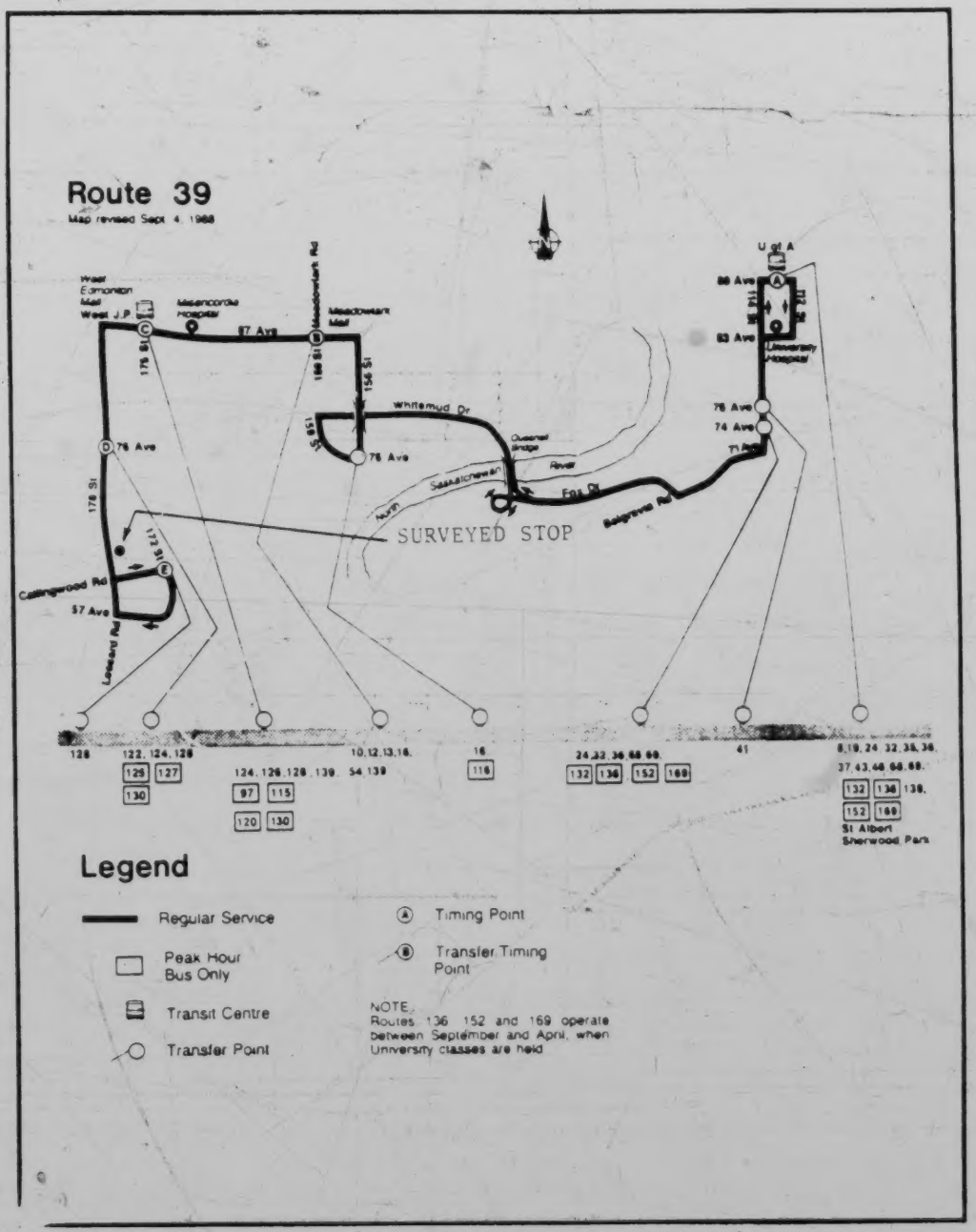


Figure 5.6 Route 39 Surveyed Stop.

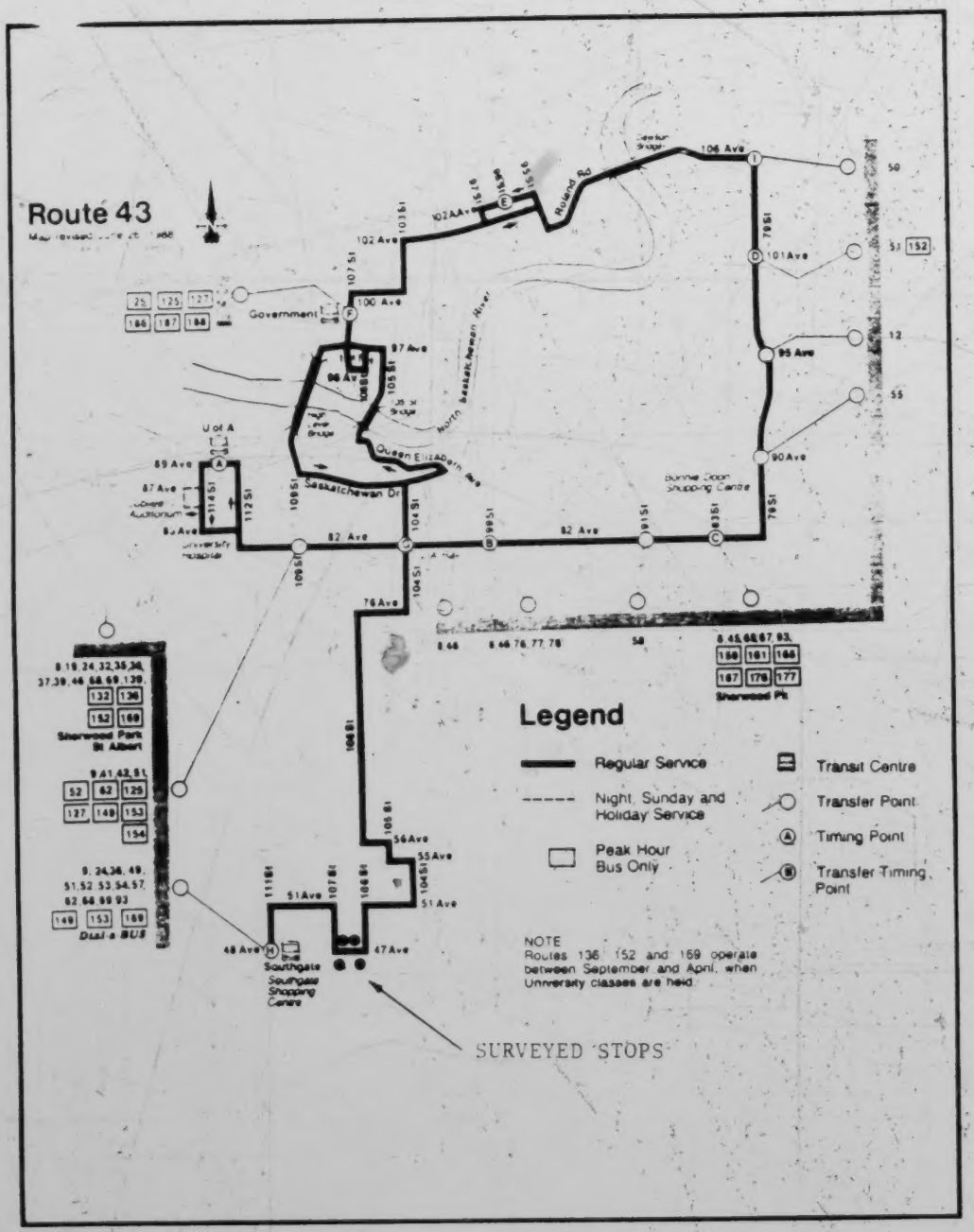


Figure 5.7 Route 43 Surveyed Stops.

their waits at the observed stop crossed the street to board an oncoming southbound bus.

Another incentive to board southbound buses was noticed. Some of the northbound buses had significant seated loads. Thus in order to get a desired seat, one could board a southbound bus. This "desired seat incentive" seems most prevelant in Junior High School students who, in the author's experiences, seem to prefer rear bus seats.

Because the service was being used on both sides of the street, the effective average headway became less than 15 minutes. Thus, data from this stop were not included in subsequent analyses.

5.2.2 Route 5, 114 Ave - 124 St

Because this stop was close to a stop for Route 3 transfers were possible. Thus the interviewer carefully watched for passengers approaching from the Route 3 stop. If a transfer was suspected, then passengers were asked, "Did you just get off from the 3?". About three observed passengers were transfering and as a result they were not included in any data analysis.

5.2.3 Route 43

Two passengers, interviewed together at a westbound Route 43 stop, mentioned that if they miss the bus they walk (about 500m) to the Southgate Transit Terminal. Therefore, long waits at this stop may be less frequent as passengers

have an alternative transportation choice. Both observed westbound stops could be competing with the Southgate Transit Terminal, as passengers may be willing to walk a longer distance in order to receive better (more frequent and diverse) service.

Despite these possible problems the data were kept. The walking distance is long (minimum of 600m) and circuitous, as AM Peak passengers must walk around Southgate Mall.

All Route 43 stops observed were close together (see Figure 5.6). As a result one passenger was interviewed twice, once in each direction. However, due to the "random" appearances made by the observer at these stops, it is unlikely that she could have predicted the observer's presence. Thus both observed wait times for this passenger were kept..

5.2.4 Route 18, 118 Avenue - 34 Street, Westbound

This was the only stop that was not in a residential location. Medium density housing is on the opposite corner from the observed stop. All other corners have commercial development. The stop was surveyed from 9:15 - 10:15, when it was less likely that shopping or work trips would be ending. However, the interviewer was aware of this possibility and discovered two such trips. They were not included in any data analysis.

5.2.5 Routes 5 and 29, Stops Surveyed Twice

Table 5.1 shows that stops on Route 29 and on Route 5 were surveyed twice. To minimize the chance of surveying passengers twice, they were observed at different times of the day. Also the passenger usage was low, and the observer remembered the passengers previously interviewed. These stops were observed twice to collect more Midday and Saturday schedule period data, where trip purposes other that work or school were more likely to be observed.

5.3 Wait Time Data

No problems were found with the watch calibration procedure. However, the bus departure time and passenger arrival time definitions were well tested.

5.3.1 Bus Departure Times

Departure times for buses were measured as previously defined, to the nearest five seconds. However, on two occasions the bus doors closed, the bus pulled about two bus lengths away from the curb, and then the bus stopped for another passenger. For one of these cases (Route 3, 117 Avenue - 124 Street, Southbound), the bus was delayed about 25 seconds while waiting for a passenger to cross the street.

For both cases the second door closing time was used to define the bus departure time.

5.3.2 Passenger Arrival Times

Passenger arrival times were measured to the nearest five seconds. The passenger arrival time definition was upheld as closely as possible, but there were problems. When interviewing, passenger arrivals and/or arrival times were missed. The observer tried to watch for such arrivals, and even recorded arrival times during interviews. But some arrivals were not noticed until the completion of an interview. In this case, the arrival time was noted as the time that the passenger was first noticed. Thus, since the interview took from one to two minutes to complete, the largest possible error in the measured wait time is one to two minutes. This procedure may skew measured wait times for busy buses, where more than about five passengers boarded a bus at the observed stop.

For some passengers who arrived during interviews but were not noticed until later, no attempt was made to estimate their arrival time. This occurred at very busy stops, where the interviewer was constantly interviewing. This procedure was followed because:

1. The observer felt that such passengers may have been waiting longer than one interview. Thus the measured wait time error may be large.
2. In some cases, the observer was uncertain as to if their arrival times had been previously recorded.

This procedure was not used frequently. About five passenger arrival times may not have been recorded.

One possible procedure to confirm the number of observed passengers is to count passengers boarding. However, the observer did not think of this immediately and sometimes the observer was still recording data during the boarding period.

5.4 Weather Data

Observations for this study were made in the Fall, when temperatures were generally declining as the weeks passed. Air temperatures ranged from approximately +3 ^{o}C to -8 ^{o}C. No precipitation occurred during passenger arrivals. Passenger behavior seemed to be sensitive to the declining temperatures, as more "bad" weather days were recorded as the weeks passed. However, as the temperatures began a slight increase, more "good" weather behavior was displayed. This occurred despite recorded temperatures that gave bad weather behavior a few weeks earlier. Thus it seemed that similar weather conditions did not produce similar passenger behaviors.

On some days it was difficult to classify the weather as "good" or "bad", as passenger response to the weather seemed to vary between individuals. For these days, "ok to bad" and "ok to good" categories were created.

A summary of the subjective weather classification data and the objectively measured data is given in Appendix E.

5.5 Group Arrival Data

Thirteen group arrivals were observed. No problems were encountered collecting these data.

5.6 Passenger Interview Data

Of the 230 passenger wait times observed, only 136 had complete interview data associated. Most of those missed waited less than five minutes, thus inducing a sampling bias for the interview data. This bias will be examined more closely in the Analysis section. The bias could have been significantly reduced if two interviewers/observers were present, although some degree of coordination between the two observers would be required so that no waits are duplicated or missed.

Often, before introducing himself as a university student conducting research on waiting time and asking passengers if they were willing to participate in such research, the interviewer would ask:

"Are you going to catch the bus here?"

Usually the answer was a fore-gone conclusion, but this question served as a better starting point for the interview.

Also, to help passengers with the interview, the interview form was usually made visible to them, and the interviewer pointed to the questions/answers as they were read.

The "Thank-you" letter was slightly altered. Also, each of the interview questions had some problems. As a result three were re-worded after the first week of observations (Oct 29, 1989 to Nov 1, 1989). These changes are discussed below.

5.6.1 Interview Question 1, Trip Purpose

Some persons thought that this question was too personal until the interviewer clarified the level of detail required by reading the list of possible responses. Therefore, interview question 1 was changed to read:

"Are you going to:

Work? School? Shopping? Recreation? Other?"

Usually after the work and school options were stated, passengers indicated their trip purpose and the remaining options were not read. This wording leads directly into the level of detail required, and passengers no longer found the question personal.

The new wording also dropped the type of school trip. For the purposes of this research it was felt that more detail of school trips was not required. It also helped to speed up interviews for the numerous school trips encountered.

5.6.2 Interview Question 2, Experience

This question was changed to read:

"How many times did you catch the bus at this stop in

the last week?"

The trip purpose condition was dropped. Any experience at the stop, regardless of trip purpose or time of day, was thought to be relevant. This also simplified the question for passengers as they no longer had to recall their trip purpose for each bus trip made in the last week. There were some indications that passengers were not paying close attention to this level of detail. For example, for the data collected on November 14 and 15, 1988, there were only four working days "in the last week". Yet most passengers gave the typical response of "five" times caught "in the last week."

Keeping the trip purpose condition would likely confuse passengers, and produce variations in the data due to differences in the level of understanding each passenger had of the question. Data from the original wording were kept, as it was felt that this change would not alter many passenger responses.

With respect to the "in the last week" condition, the words "in the" were explicitly added. They had already been pencilled in on the original interview forms. It was hoped that adding these words would help prevent passengers from thinking of trips made during weekdays only. However there was still some confusion. Some persons counted the interview day. The interviewer clarified the question if passengers seemed confused by stating "Not counting today." Other persons counted the current work week only. They stated,

"This is Monday, its my first time this week." Again the interviewer clarified the question, this time by stating "...in the last seven days." Using "...in the last seven days." may have been the best wording for this question.

Another problem with the trip purpose question is that a frequent user may not have used the bus "... in the last week." For example, one gentleman stated that he was on holidays during the previous week. Two such cases were encountered, and both were classified as frequent (i.e. five times in the last week) users for the purposes of the data analysis.

5.6.3 Interview Question 3, Schedule Knowledge

Some passengers may not have been completely familiar with the nearest upstream timing point's location, or the direction that the bus departed this timing point (which usually was not included in the question). To help orient passengers, the interviewer usually pointed in the general direction of the timing point.

An interesting reaction to the schedule knowledge question by some passengers was noticed by the interviewer. They seemed to be puzzled that the interviewer was asking what time the bus left some stop other than the one they were using. The look on their faces seemed to say "Why are you asking me what time the bus leaves that stop?" or "What good is that to me?" or "That location seems rather arbitrary!". This was especially noticeable for the

westbound stops surveyed on Route 43, as the nearest upstream timing point is about 14 minutes distant by bus travel time. Very few passengers at these two stops correctly answered the schedule knowledge question. Such reactions by passengers probably indicate limited understanding of using timing points to estimate the bus's arrival time, or the difficulty in estimating the bus travel times from distant timing points.

For the surveyed stops along Route 30, a few passengers seemed to believe that they were being asked what time the bus departs their neighborhood, not the timing point. This is likely due to the bus actually passing the timing point's street address twice, as the route is looped (see Figure 5.4). Giving the bus's direction may have reduced the confusion.

Whether passengers are confused about the direction the bus departs a timing point or about the location of a timing point is not damaging to the research question. In fact, it shows that they have limited schedule knowledge. Passengers who were familiar with the schedule understood the question. Many persons correctly and confidently answered this question.

5.6.4 Interview Question 4, Method of Payment

It was found that some passengers claiming to use the bus five or more times per week paid for their trip by cash. At first this seemed surprising. However, this result was

confirmed by a fare survey conducted by Edmonton Transit in October and November 1988.

There were good reasons for such behavior. At the time of the surveys, a low price differential existed between monthly pass and cash payments. A monthly pass cost $36, while the cash fare was $1 per trip. For twenty one-way trips per month, the cash fare would be $40. However, if some passengers are able to get some rides during the course of the month, or if they go on holidays, or if they work compressed work weeks, then it becomes more economical to pay by cash. In addition to economic reasons, there is also the risk of losing the pass and having to pay cash fares for the remainder of the month. Thus the incentive to purchase a monthly pass was low.

As a result of this peculiarity, interview question 4 was not used as a check on passenger response to frequency of use (interview question 2), or to validate responses.

5.6.5 Interview Form and Thank-you Letter

Final versions of the "Thank-you" letter and the interview form are shown in Figures 5.8 and 5.9 respectively. These versions were used from Saturday, November 5, 1988 to Tuesday, November 29, 1988.

The "Thank-you" letter was placed on University of Alberta Department of Civil Engineering letterhead, to help legitimitize the interviewer's presence. Neither version of the "Thank-you" letter had problems. No post-interview

University of Alberta
Edmonton
Canada T6G 2G7

Department of Civil Engineering

223 Civil Electrical Engineering Building
Telephone (403) 432-4235

Dear Passenger,

Thank-you for participating in this research. If you have any questions or concerns regarding this study, you may contact:

Marcel Huculak (Interviewer)
Room 219J
Civil Engineering Building
University of Alberta
EDMONTON, Alberta
T6G 2G7
ph. 432-2795

Professor J.J. Bakker (Supervisor)
Department of Civil Engineering
Civil Engineering Building
University of Alberta
EDMONTON, Alberta
T6G 2G7
ph. 432-5112

Yours sincerely,

Marcel Huculak

Marcel Huculak

DATE:_____ DAY:_____ ROUTE:_____

LOCATION:_____

ARRIVAL TIME:_____ BUS ARRIVAL TIME:_____

1. Are you going to:

__WORK __SCHOOL __SHOPPING __RECREATION __OTHER_____

2. How many times did you catch the bus at this stop in the last week?

__0 __1 __2 __3 __4 __5 __5+_____

3. Do you know what time this bus is scheduled to depart _____?

__NO __YES; WHAT IS THAT TIME?_____

4. How will you pay for your trip?

__CASH __PASS __TICKET __TRANSFER

ARRIVAL TIME:_____ BUS ARRIVAL TIME:_____

1. Are you going to:

__WORK __SCHOOL __SHOPPING __RECREATION __OTHER_____

2. How many times did you catch the bus at this stop in the last week?

__0 __1 __2 __3 __4 __5 __5+_____

3. Do you know what time this bus is scheduled to depart _____?

__NO __YES; WHAT IS THAT TIME?_____

4. How will you pay for your trip?

__CASH __PASS __TICKET __TRANSFER

contact was received from any interviewed passengers.

The interview form served an additional function of providing room for notes that the observer would scrawl in margins. These notes included passenger arrival times during interviews, peculiar passenger bahaviors and problem descriptions for any data collected. This helped the observer to recall experiences, leading to an appropriate treatment of data for analysis.

5.6.6 Interviewing Groups

Many persons arrived in groups, usually of two. In most cases they were interviewed together. It was more convenient for them, and it was feared that asking them to split up would arouse suspicions.

This procedure is not ideal. One passenger's response to a question may influence the remaining passenger's response. This is also a problem when separate passengers are within ear shot of each other, especially in passenger shelters. In one case (Route 43, 47 Avenue - 106 Street, Eastbound) a passenger seemed to "agree" with the scheduled departure given by a previously interviewed passenger. He responded "Ahhh...yeah, 7:22." His resonse was correct, but it was decided that for the purposes of the analysis, his schedule knowledge was classified as "not perfect".

5.6.7 Interview Refusals

Two persons refused an interview. One may not have been able to speak English. The second appeared to be mentally handicapped and perhaps did not understand the interviewer's purpose, thus becoming suspicious of the interview. In both cases, once the passenger said "No", no further attempts were made to obtain an interview. Also, the interviewer should have offered these persons the "Thank-you" letter, providing an opportunity to express their concerns to the interviewer's supervisor. This was not done. It was not considered until after the data were collected.

One other person may have intentionally avoided an interview by stating that he was catching the bus across the street from the observed stop (Route 43, 47 Avenue - 106 Street, Eastbound). He said that he does this when he feels that he missed the eastbound bus. However, he did catch the bus at the observed stop. His wait was recorded.

Finally, some persons seemed reluctant to participate in the interview. They expressed reservations by not responding immediately to the interview request but seeming to decide, or by asking the interviewer "What do you mean by non-personal questions?". In these cases the interviewer asked:

> "How about I ask the questions, and if you don't want to answer, just say so."

None of these persons refused to answer any interview questions, and one expressed relief when she saw that the

questions truly were "non-personal".

5.7 General Data Collection Problems

Some general problems encountered with the data collection procedure are detailed below.

5.7.1 School Special Buses

On Route 39 (64 Avenue - 178 Street, Northbound) and Route 43 (47 Avenue - 106A Street, Eastbound, on Tuesday November 1, 1988 only) extra buses were inserted on top of the regular service to handle high loads generated from school trips. As discussed previously, the Route 39 data were discarded due to other problems. However, for Route 43 it was a concern as the extra bus and the regular bus did not arrive simultaneously. They were separated by 110 seconds, thus changing the observed headways. However, no one caught either bus at the observe stop and thus no data were affected.

No school special was observed on Route 43 at 47 Avenue - 106 Street, Eastbound, when it was surveyed on Tuesday November 8, 1988.

5.7.2 Obtrusive Observations

On Route 43, at 47 Avenue - 106 Street, Eastbound, on November 1, 1988, a passenger walked past the observed stop to a downstream stop. It may be that this person saw the observer recording data and became suspicious. But it may be

that this person wanted to wait in the shelter at the downstream stop, or felt more secure at that stop as it was better lit.

When Route 43, at 47 Avenue - 106 Street, Eastbound, on Tuesday, November 8, 1988, was surveyed the school special was not observed. This was evidently due to a re-routing by Edmonton Transit, as the bus driver on the regular run asked the observer:

"You wouldn't be waiting for that school bus?"

This indicates that the bus driver thought that the observer was a passenger, and became concerned when the observer did not board the bus. Thus the driver did not think that the observer was recording bus arrival data.

As noted earlier some drivers picked up passengers away from the curb. This is against Edmonton Transit safety guidelines, but is not uncommon practice. However, the fact that they did this in the observer's presence indicates that these drivers were not concerned about the observer's presence.

These three incidents give some idea of the observer's impact on the persons observed. No other unusual behavior by drivers or passengers was observed. Thus, it seems that the observer's impact on the drivers and passengers was minimal, and that the data extracted are valid observations of their behavior.

5.8 Conclusions and Recommendations

Designed to collect data on passenger trip purpose, experience using the bus, and schedule knowledge, the interview process was generally successful. Interviews allow questions to be clarified, and the interviewer gained information from passengers regarding the true research questions rather than the "surrogate" interview questions. There was a very low refusal rate on the interviews (two refusals compared to 136 completed interviews). No complaints were received.

However, one problem with interviews is that a sampling bias is introduced. This bias could be reduced if two interviewers were used at the stop, although it is unlikely that such a bias could ever be eliminated.

The observer's presence at the stop did not seem to affect the arrival time behavior of either passengers or bus drivers. This may be attributed to the precautions taken to minimize the observer's impact on drivers and passengers. Thus the data are thought to be valid observations of wait times and of passenger trip purpose, experience, and schedule knowledge.

6. Analysis of Wait Time Data

6.1 Introduction

The purpose of this chapter is to present the results of the data analysis and to describe the analysis techniques used, including their underlying assumptions. As discussed in Chapter 5, problems with the data collection method led to the rejection of some data. Analysis is limited to the remaining portion of data.

This chapter is organized as follows. First the analysis techniques used and their underlying assumptions are presented. Then the effects of weather and group arrivals on wait time are examined. The passenger interview data is then used to examine the effects of trip purpose, schedule knowledge, and experience on waiting time. The effects of weather and group arrivals are examined first to "screen out" possible effects upon the passenger interview data. Finally, the findings of each analysis are summarized.

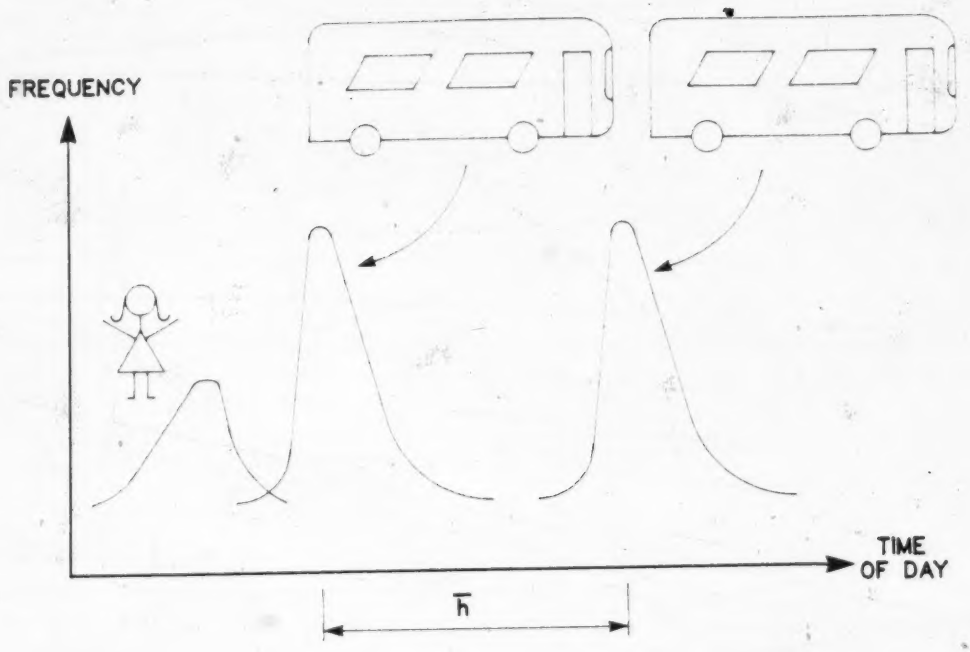
6.2 Analysis Techniques Used and Assumptions

The analysis techniques used and their underlying assumptions are each described in the following sections. Much of the analysis involved statistical procedures. Most data analyses were performed on the University of Alberta's Michigan Terminal System (MTS) mainframe computer, using the SPSS^{X} software package.

6.2.1 Wait Time Distributions

Each analysis in this chapter is based on a comparison of two or more wait time distributions. These wait time distributions can be thought of as the sum of several individual passenger wait time distributions, composed of an individual passenger and two particular bus arrival time distributions. For example, suppose that a particular passenger, the bus she is to catch, and the bus immediately after, have arrival time distributions (measured over several days) as illustrated in Figure 6.1. The wait time distribution that may result from these is also illustrated in the lower portion of Figure 6.1. Clearly, any change in one of the component distributions will impact the observed wait time distribution. If either passenger or bus arrival distributions were random (i.e. a horizontal line), then the wait time distribution would be uniform. It is hoped that random passenger arrivals can be explained by the passenger data measured (amount of experience and schedule knowledge, and trip purpose). However, if the bus arrival distributions were random, then passengers could not predict bus arrivals. The explanatory power of the measured passenger data would then be lost. Therefore, it is assumed that bus arrivals are not random, but rather that the buses have some degree of reliability.

Directly confirming bus reliability requires observing bus arrival times at the same stop for several days. This process is time consuming and was not done in the data



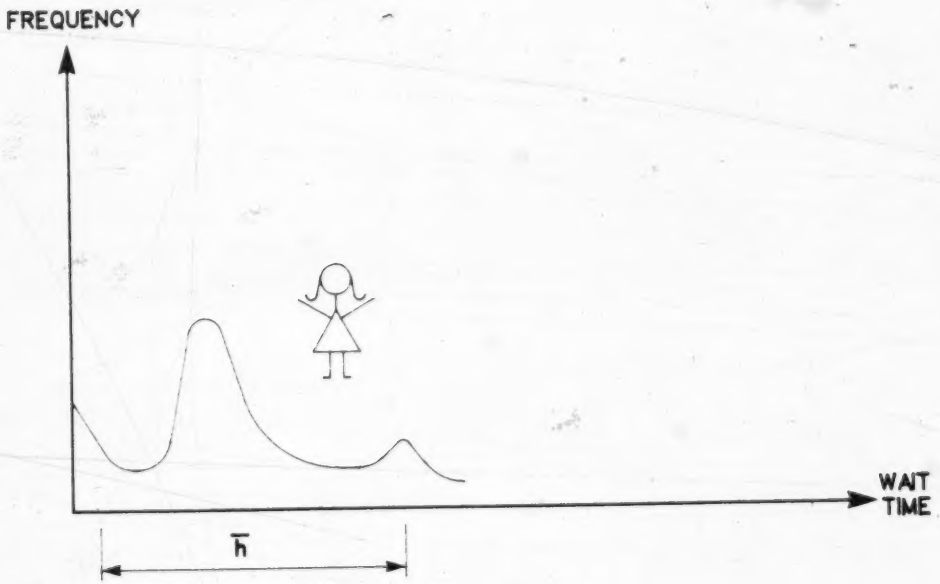


Figure 6.1 Components of an Individual Passenger's Wait Time Distribution

collection procedure. Instead, as an indirect proof of bus reliability, the reader will note that most of the wait time distributions presented are not uniform but skew to the left. Most waits are less than half the headway. This is clear evidence that at least some passengers were able to predict bus arrivals and that buses were reliable.

6.2.2 Sampling Bias for Interview Wait Time Distributions

Because each passenger interview took about one minute to conduct, passengers with smaller waits were not interviewed. Also, at busy stops a queue of non-interviewed passengers would form. A sampling bias occurred as a result of these real constraints.

Figures 6.2 illustrates the sampling bias. It shows the wait time distribution of all observed waits and the wait time distribution of all interviewed passengers. Interviewed passengers with waits less than five minutes are under-represented when compared to the overall population of observed waits.

Jackson (1977) had a similar sampling bias with his interview data. For his research, he compensated for the under-representation of short waits by dividing the wait time distributions into equal segments and then, for each time segment, scaling up the number of observations in his interview data by the same proportion represented in the overall wait time distribution.

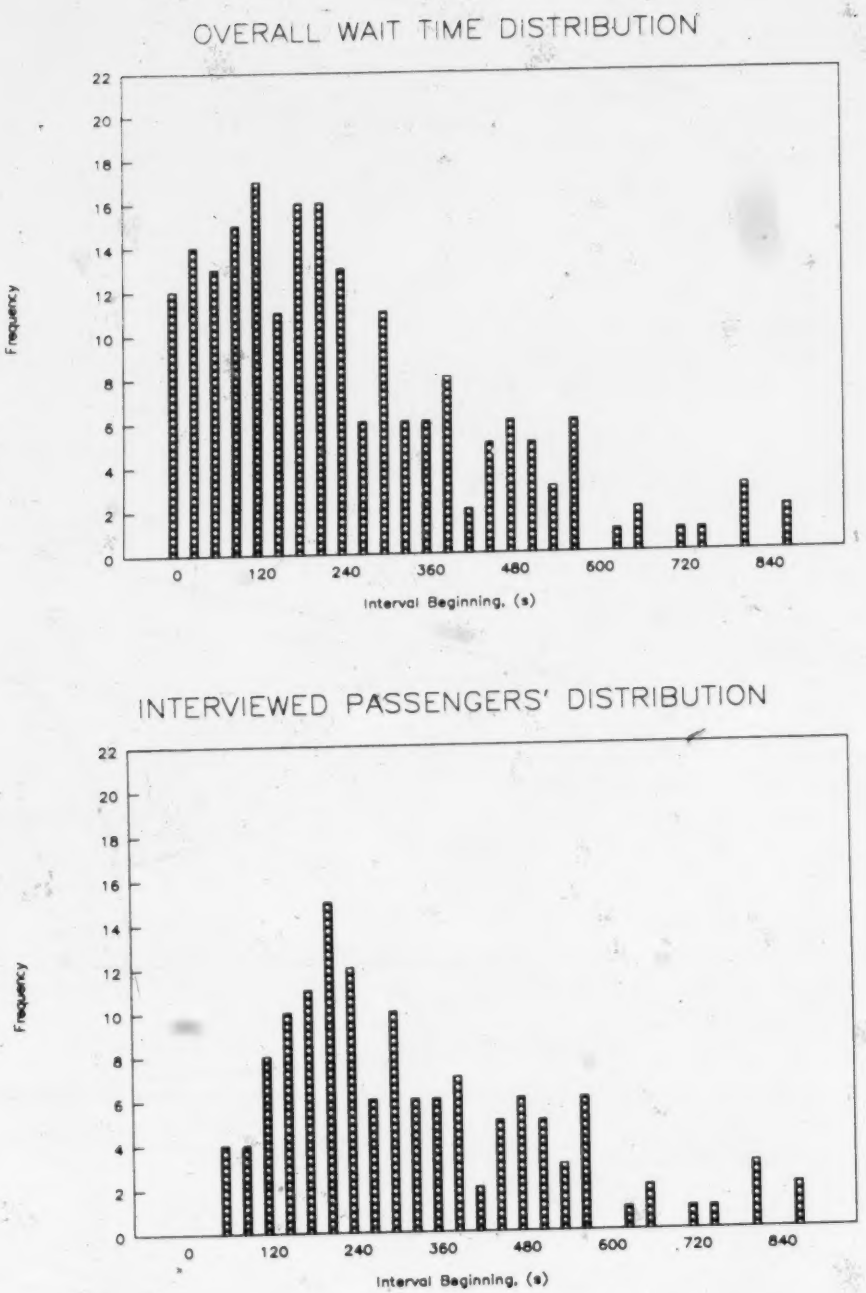


Figure 6.2 Wait Time Distributions of All Observed Passengers and of All Interviewed Passengers.

Jackson's (1977) method was deemed inappropriate for this research. There are few interview data in the first two to three minute time slice. Thus its accuracy is in question. Further, if it were inaccurate, any errors would be scaled up by the large proportion of passengers observed in the first time slice.

For this research the absolute values of the waits are irrelevant. What is relevant is the effect that trip purpose, schedule knowledge, or experience have upon wait time. Such differences may be seen by comparing the sampled distributions. Therefore, no sampling bias correction will be applied.

It is possible that the sampling bias may make two similar wait time distributions different, especially if the difference is within the first time segment. Figure 6.3 illustrates this possibility. While the true distributions differ, the sampling bias (simplified as rejecting all short waits) hides the difference.

It is assumed that the sampling bias will not have this effect. There were some interviews with short waits, helping to establish the trend of the first time segment. Also, it seems likely that the distributions differ in more ways than that illustrated in Figure 6.3. Such differences will be apparent despite the sampling bias.

It should also be noted that if two real distributions are the same, the sampled distributions should also be the same, as the sampling bias would effect each equally.

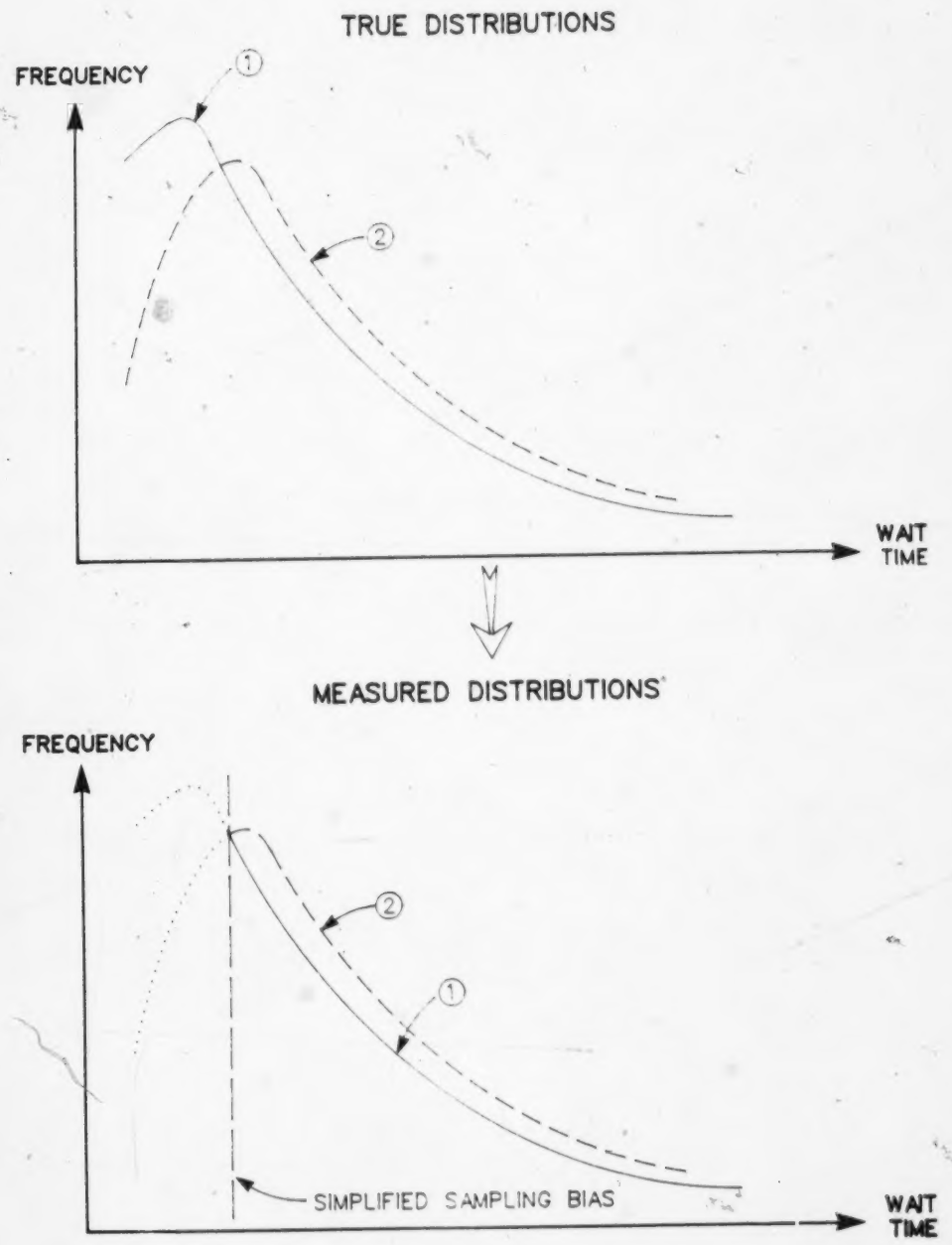


Figure 6.3 Two Differing Wait Time Distributions made Similar Through a Sampling Bias.

Therefore, if two sampled distributions are found to be similar, the actual distributions are likely similar. Uncertainty arises when two sampled distributions are found to be different. The difference may be due to the interview sampling bias or to some underlying cause. As with many statistical methods, observed differences which are supported by other evidence are more plausible.

6.2.3 T-Test

The following description is based on Kennedy and Neville (1976) and on Davies and Goldsmith (1976).

The T-test is a method of comparing sample means. The test is applied to a null hypothesis that the two sample means are drawn from the same population, and that any difference in sample means is due to chance alone. The sampled distributions should be approximately normal. If the sample variances s_1 and s_2 are approximately equal, the t statistic can be calculated using the pooled variance:

$$t = \frac{|\bar{x}_1 - \bar{x}_2|}{s_p}$$

with degrees of freedom:

$$\nu = \nu_1 + \nu_2 - 2$$

and where:

$$s_p = \left(\frac{n_1+n_2}{n_1 n_2}\right)^{1/2} \left(\frac{s_1^2\nu_1 + s_2^2\nu_2}{\nu_1+\nu_2}\right) = \text{pooled variance}$$

n_i = number of observations in sample i

s_i^2 = estimated variance of sample i

$\bar{x}_i$ = mean of sample i

ν_i = degrees of freedom for sample i = $n_i - 1$

i = the sample number = 1,2

If the sample variances differ significantly, then the t-statistic can be calculated using the separate variance:

$$s_s^2 = \frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}$$

with degrees of freedom calculated by:

$$\frac{1}{\nu} = \frac{1}{\nu_1}\left(\frac{s_1^2/n_1}{s_1^2/n_1 + s_2^2 n_2}\right)^2 + \frac{1}{\nu_2}\left(\frac{s_2^2}{s_1^2/n_1 + s_2^2 n_2}\right)^2$$

Sample variances can be compared using the F-test.

T-test results in this working paper are summarized by giving each distribution's mean, the calculated t value (t_{calc}), and the corresponding level of significance, α. The level of significance is the probability that the observed difference is due to chance alone. A low level of significance would indicate that the observed difference is likely a result of some underlying mechanism.

6.2.4 F-Test

This F-test description is based on Kennedy and Neville (1976) and Newbold (1988).

In comparing two samples, it is possible that the means are identical, but one sample's data is widely spread relative to the other sample's data. Therefore the samples are from different populations. To formally test for such a possibility, sample variances may be compared.

The F-test is a common method of comparing sample variances. The null hypothesis is that there is no statistically significant difference in the variances, that is $s_1^2 = s_2^2$. The F-test gives the probability of the observed difference being due to chance alone as equal to α, the level of significance. As with the T-test, a low level of significance would indicate that the observed difference is likely a result of some underlying mechanism.

Larger samples generally have more accurate variances. Therefore it is advantageous to have large samples for the F-test. Suggested sample sizes are greater than about 30.

There are two limitations of the F-test. First, if the variance is a function of the level of the mean and the samples have different means, the F-test cannot be applied to the variances. For the analyses in this research, either the means are not statistically different or the differences in variances may be attributed to other factors. Therefore, it is assumed that this limitation does not apply.

The second limitation of the F-test is that the data must be normally distributed. The following section describes a procedure for testing sample normality.

6.2.5 Sample Normality

Normally distributed data are required for the F-test. Two normal distribution tests are used in this research. Generally, for a distribution to be considered as normal, it must pass both tests.

The first normal distribution test is a subjective test. The data are plotted in a frequency distribution and a visual inspection is made. If the data appear normally distributed - that is, there are no obvious skew or bimodal appearances, further testing proceeds.

The second normal distribution test is the Bowman-Shelton test (B-S test), described in Newbold (1988). The test adopts the null hypothesis that the distribution does not differ from a normal distribution. Then, based on the distribution's skewness and kurtosis, a B-S statistic is generated and compared to that which may be expected for a given number of degrees freedom and a significance level α. The approximate probability that the actual distribution is not normal can then be infe ed.

The B-S test works best for larger samples, usually of more than 20 observations. If the data are not normally distributed a transformation is required.

6.2.6 Data Transformations

Johnson and Wichern (1982) state that "Transformations are nothing more than a reexpression of the data in different units.". To transform a data set, each element x_i

in the data set X is put into a function $f(x_i) = y_i$, such that the elements y_i in Y form a new distribution. Normal distribution tests can then be conducted on Y.

The new distribution Y may lose some of its physical meaning in the transformation. For example, a common transformation is the log transformation:

$$y_i = \log(x_i)$$

The y_i in Y have no physical meaning, but serve merely to facilitate statistical analysis.

6.2.7 ANOVA

ANOVA is an acronym for ANalysis Of VAriance. It is a method for comparing two or more sample means, where several "treatments" have been randomly allocated to the "experimental material" (Box et al (1978)). In this research, the "treatment" is trip purpose, as several trip purposes are possible. The "experimental material" is wait time.

ANOVA is a relatively complex analysis procedure. Details are provided in Appendix A.

6.3 Statistical Analysis of Data

The following sections detail the procedures and the findings of the statistical analysis. First, an overview of the wait time date collected is presented. Then the effects of group arrivals and weather are examined. Finally the interview data are used to explore the effects of passenger

schedule knowledge, experience, and trip purpose.

6.3.1 Wait Time Characteristics of Observed Passengers

The wait time distribution and corresponding cummulative distribution for all observed passengers are shown in Figure 6.4. The distribution is heavily skew to the left, indicating that at least some passengers were able to predict bus arrivals. Therefore it is assumed that the buses are reliable, and that using wait time distributions to compare passenger arrival behavior is valid.

For the 201 passengers observed, the average wait time was 255 seconds (4:15), with a standard deviation of 192 seconds (3:12). About 66% of the passengers waited less than 5 minutes (300 seconds), while 5% waited longer than 10 minutes (600 seconds).

6.3.2 Effect of Weather

Each observed wait time was grouped in "good" and "bad" weather categories. Those days originally classified as "ok to good" and "ok to bad" were classified as "bad" weather days. Resulting wait time distributions are shown in Figure 6.5. Group arrivals are treated as separate individual arrivals in these distributions. Both distributions are skew to the left. Average wait times are 271 seconds (4:31) for "good" weather and 244 seconds (4:04) for "bad" weather.

Both distributions fail the normal distribution tests. Details are provided in Appendix B.1. A square root

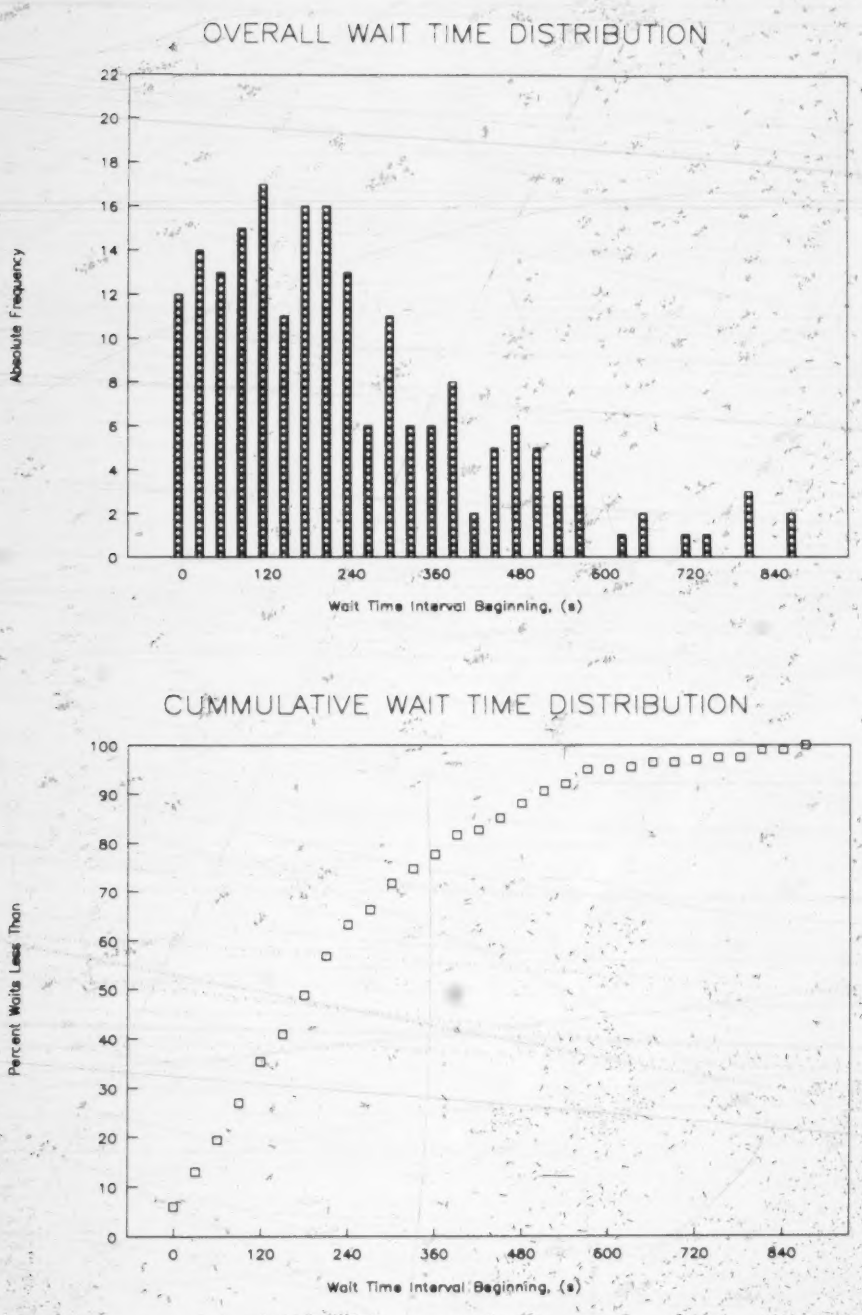


Figure 6.4 Overall Wait Time Distribution of Observed Passengers and Their Cummulative Wait Time Distribution.

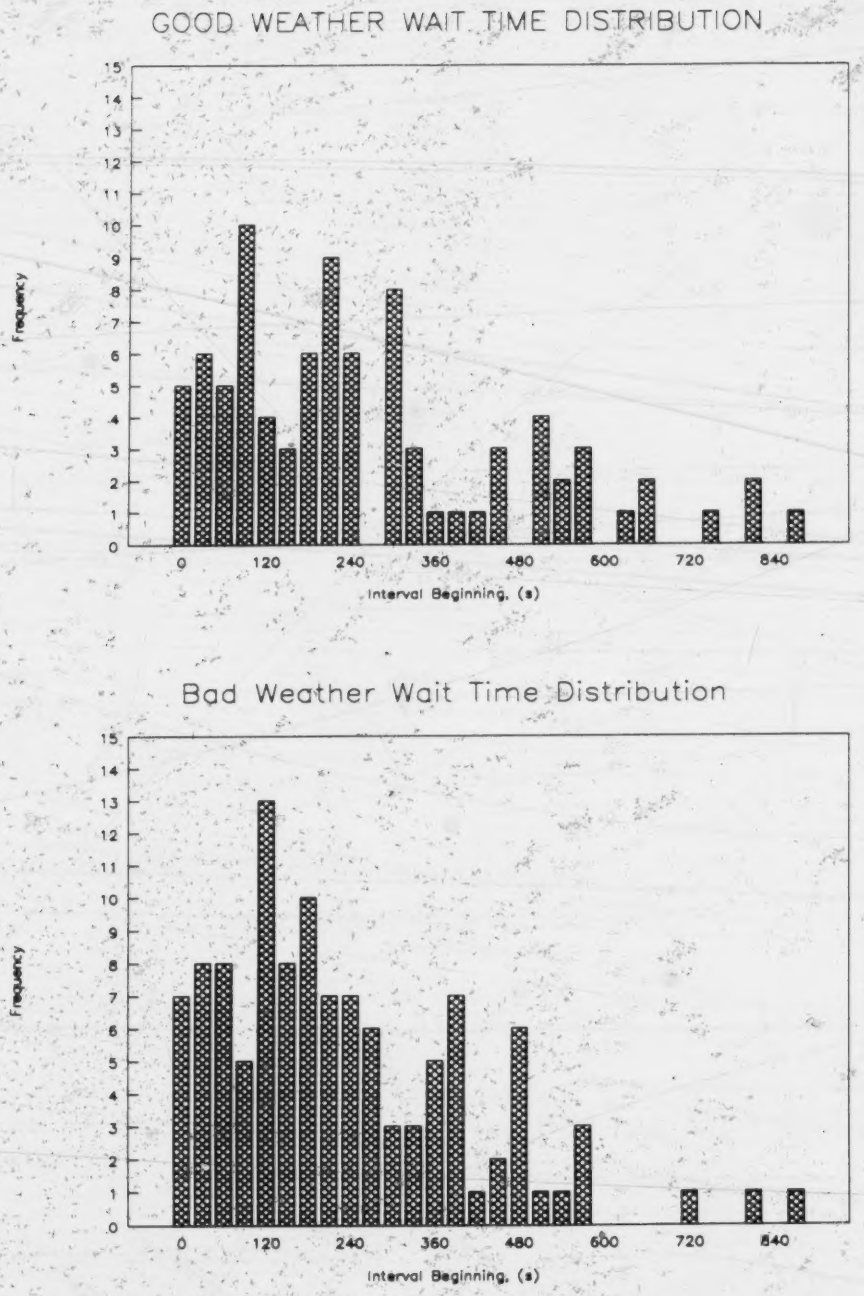


Figure 6.5 "Good" and "Bad" Weather Wait Time Distribution.

transformation (i.e. $y_i = f(x_i^{1/2})$) successfully produced normal distributions (see Appendix B.2).

Statistical data for the square root distributions are summarized in Table 6.1. The F-test indicates that there is a 23% chance that the observed difference in variances is due to chance alone. While this may indicate some underlying trend, it is not conclusive. When comparing the two square root wait time distributions (Figure 6.6) there is no apparent difference in variance.

The T-test is even less conclusive. There is a 50% chance that the observed difference in the mean root wait times is due to chance alone. The observed difference in actual average waits is only 27 seconds. This is about 10% of the average waits and can be expected given the high variance of the data.

Therefore, for the purposes of further data analysis, it is concluded that the weather observed in this study was not a strong influence on bus passenger waiting time. In succeeding analyses, data are not segregated by weather, but are kept together.

Although the evidence is not strong, the F-test tends to show that the variance of waits in "good" weather is larger than that for "bad" weather ($\alpha = 23/2 = 11.5\%$, i.e. a one sided F-test, with the alternative hypothesis that $s_{good} > s_{bad}$, rather than $s_{good} = s_{bad}$). It may be that "high risk" passengers display different behavior depending upon the weather. On "good" weather days they time their

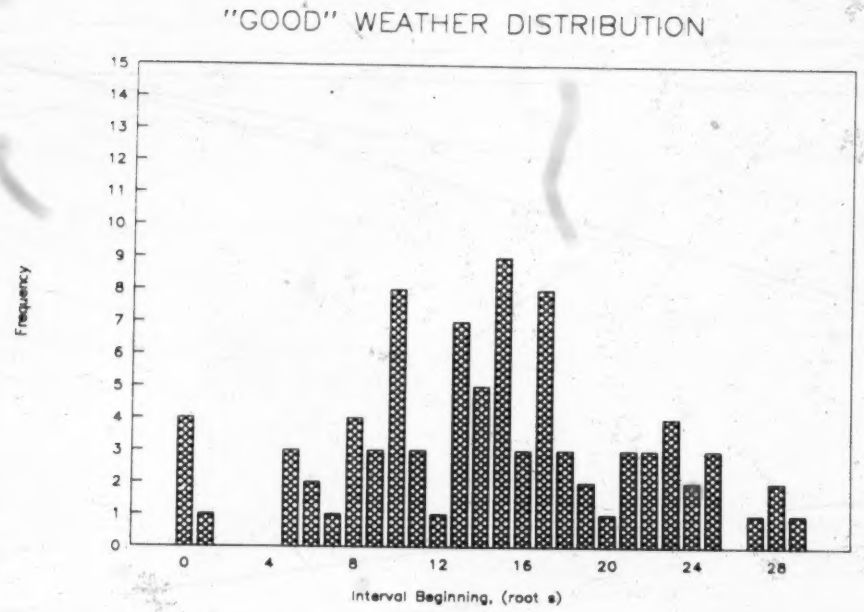
Table 6.1 Statistical Summary of "Good" and "Bad" Weather Square Root Wait Time Distributions.

	"GOOD"	"BAD"
Number of Observations	87	114
Average Wait (square root seconds)	15.1	14.4
Standard Deviation (square root seconds)	6.72	5.96

F calc = 1.27 ALPHA F = 23%

T calc = -0.67 ALPHA T = 50%

CONCLUSION: Not Significant



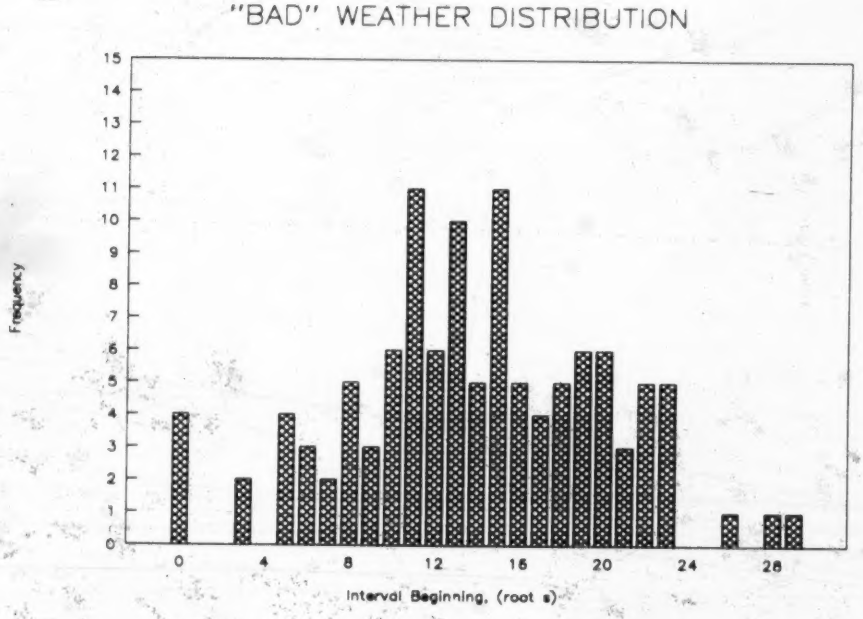


Figure 6.6 "Good" and "Bad" weather Square Root Wait Time Distribution.

arrival closely to that of the bus's (occasionally missing it and having a long wait). On "bad" weather days they may reduce their risk by arriving earlier, thereby reducing the chance of missing the bus. Thus the "tails" of the "good" weather root wait time distribution move into the middle on "bad" weather days, and the variance decreases.

It was also noted during observations that one passenger walking toward a stop returned home after she saw the bus pass by. This behavior may be more common during "bad" weather, and may account for an apparent lack of waits longer than 10 minutes (600 seconds) on "bad" weather days (see Figure 6.5).

Weather differences during the course of observations were subtle, and the observer had difficulty in classifying weather on several observation days. The fact that the statistical test showed some trends is encouraging, both for the method in which the weather was classified, and for the possibility that weather does indeed alter passenger arrival behavior.

6.3.3 Effect of Groups

It is hypothesized that passengers arriving in groups have different waits than passengers arriving individually. Therefore, each group arrival is treated as one wait time observation regardless of the number of passengers in the group.

Statistical data for a comparison between group and individual arrivals are shown in Table 6.2. A square root transformation (i.e. $y_i = f(x_i^{1/2})$) was used. There appears to be little reason to suspect that groups and individuals have differing wait times.

6.3.4 Effect of Groups and Weather

Analyses comparing individual arrivals in "good" versus "bad" weather, and comparing group arrivals in "good" versus "bad" weather were conducted. It is assumed that the proportion of group and individual arrivals is independent of weather.

Statistical data for individuals arriving in "good" and in "bad" weather, using a square root transformation (see Appendix B.4), are shown in Table 6.3. F-test and T-test results indicate that there is no strong tendancy for individuals to arrive differently on the "good" versus "bad" weather days observed in this study. Therefore it is concluded that individuals have similar arrival behavior for the "good" and "bad" weather days observed.

Statistical data for groups arriving in "good" versus "bad" weather are shown in Table 6.4. For this analysis, each group arrival time is treated as a single observation. The resulting numbers of observations are small. Therefore only the T-test results, using the Separate Variance Estimate Method (i.e. assuming unequal variances) is used.

Table 6.2 Statistical Summary of Groups and Individual Square Root Wait Time Distributions.

	INDIVIDUALS	GROUPS
Number of Observations	174	12
Average Wait (square root seconds)	14.6	15.2
Standard Deviation (square root seconds)	6.33	6.44

F calc = 1.04 ALPHA F = 83%

T calc = 0.31 ALPHA T = 76%

CONCLUSION: Not Significant

Table 6.3 Statistical Summary Comparing Individual Arrivals in "Good" Versus "Bad" Weather.

	"GOOD"	"BAD"
Number of Observations	75	99
Average Wait (square root seconds)	14.6	14.7
Standard Deviation (square root seconds)	6.68	6.08

F calc = 1.21 ALPHA F = 38%

T calc = 0.14 ALPHA T = 89%

CONCLUSION: Not Significant

Table 6.4 Statistical Summary Comparing Group Arrivals in "Good" Versus "Bad" Weather.

	"GOOD"	"BAD"
Number of Observations	5	7
Average Wait (square root seconds)	18.7	12.8
Standard Deviation (square root seconds)	6.76	5.36

F calc = 1.59 ALPHA F = 58%

T calc = -1.62 ALPHA T = 15%

CONCLUSION: Significant

The T-test tends to indicate that average waits of groups in "bad" weather differ from groups in "good" weather. For a one sided T-test, with the alternative hypothesis that the "bad" weather groups' average wait is less than the "good" weather groups', the level of significance α is 14.7/2 = 7.4%. This alternative hypothesis is expected. During "good" weather, a long wait in the company of others is likely less annoying than if alone. During "bad" weather groups may take more care with their arrivals.

Figure 6.7 shows the square root wait time distributions for groups arriving in "good" and "bad" weather respectively. There is very little overlap. In actual waits, "good" weather groups waited an average of 385 seconds (6:25), while "bad" weather groups waited an average of 188 seconds (3:08).

In light of the above evidence it appears that groups may be more sensitive to weather conditions than individuals. Therefore, group arrivals are not included in succeeding analyses.

6.3.5 Effect of Experience

The experience interview question asked passengers how many times they caught the bus from their stop in the last week. A variety of reponses were recorded. This dictated a need for a clear definition of "experienced" and "not experienced" passengers.

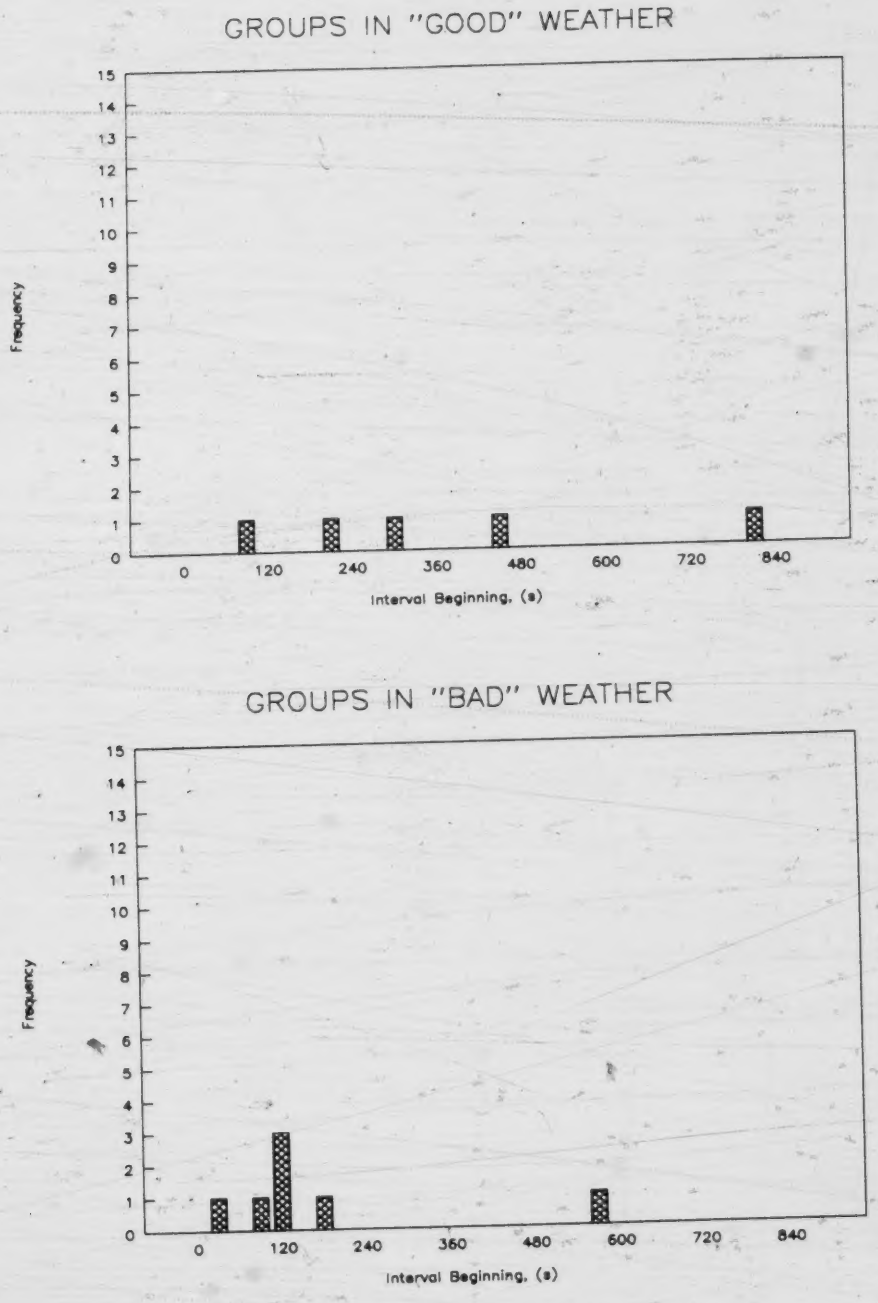


Figure 6.7 Groups Arriving in "Good" and "Bad" Weather.

Passengers who responded "5" or "5+" to the experience question can be considered "experienced". Such passengers were often work or school trips and therefore likely caught the same route at the same stop and at the same time every week day. They likely have intimate knowledge of the bus's usual arrival time. Due to some interviews being conducted after a 4 day work week it was also decided that passengers who caught the bus 4 times would be classified as "experienced".

Separate experience wait time distributions were then constructed using four definitions of "not experienced":

1. Did not catch the bus at the observed stop in the last seven days.
2. Caught the bus 1 or less times in the last seven days.
3. Caught the bus 2 or less times in the last seven days.
4. Caught the bus 3 or less times in the last seven days.

These distributions are shown in Figure 6.8.

If passengers are inexperienced at catching the bus, then it would be expected that their arrivals are random, and that their wait time distribution would be uniform. The wait time distributions for the definition of Experience ≤ 1 most closely resembles a uniform distribution (see Figure 6.8). The average wait for Experience ≤ 1 is 7:25, which is close to the expected average wait of 7:30 for random

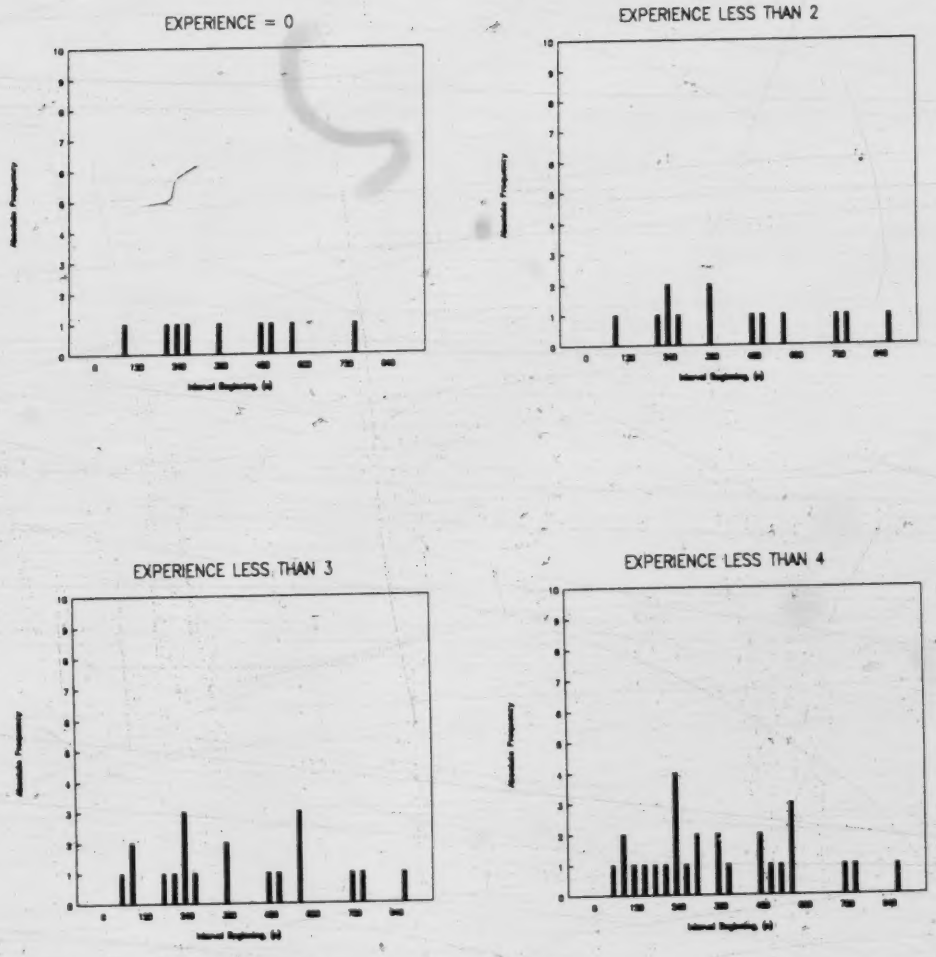


Figure 6.8 Wait Time Distributions for differing definitions of experience.

passenger arrivals with a 15 minute headway (Actually, the measured average wait should be slightly higher than 7:30, due to the interview sampling bias).

Thus, the definition of "not experienced" in this research is when EXP ≤ 1. A root 2.5 transformation was used for statistical analysis (see Appendix B.5). From the statistical summary shown in Table 6.5, the F-test indicates that the variances may differ. Indeed, if the "not experienced" passengers are uniformly distributed, then there is a difference between "experienced" and "not experienced" passengers. Even if the F-test results are rejected, and assuming that the "not experienced" passengers root 2.5 wait time distribution is normal, the T-test gives very strong evidence that "experienced" and "not experienced" passengers do have different average waits.

Therefore it is concluded that experience catching the bus at a stop is an important influence on passenger waiting time. The actual measured waits in this research, using interview data only, are 307 seconds (5:07) for "experienced" versus 445 seconds (7:25) for "not experienced". This conclusion has a significant implication for wait time modelling. It may be advantageous to separately model waits for "experienced" and "not experienced" passengers. Jackson (1977) developed separate wait time models reflecting this phenomenon. This conclusion also implies that ridership elasticities with respect to headway may be much higher for infrequent transit users, as

Table 6.5 Statistical Summary of "Experienced" and "Not Experienced" Passengers

	"EXPERIENCED"	"NOT EXPERIENCED"
Number of Observations	112	13
Average Wait (seconds EXP 0.4)	9.58	11.1
Standard Deviation (seconds EXP 0.4)	2.01	2.56

F calc = 1.60 ALPHA F = 20%

T calc = -2.04 ALPHA T = 6.1%

CONCLUSION: Significant

their waits are more dramatically impacted. Jackson (1977) also noted that the proportion of random arrival passengers decreased as headways increased.

Ploof (1990) showed that infrequent riders are a significant portion of the persons who weekly use transit. Therefore, a service frequency change may impact many passengers' waiting times and their perceptions of the service.

6.3.6 Effect of Schedule Knowledge

Passengers who correctly answered (to the exact minute) the schedule knowledge interview question ("What time does this bus depart {the nearest upstream timing point."}) were classified as having "perfect" schedule knowledge. All other interviewed passengers were classified as "not perfect" schedule knowledge.

Statistical data for passengers with "perfect" and "not perfect" schedule knowledge are summarized in Table 6.6. A fifth root transformation was used for the analysis (see Appendix B.6).

The F-test indicates that there may be a difference in the measured variances, but it is not strong. However, the T-test gives strong evidence that passengers with "perfect" schedule knowlege have shorter waits than passengers with "not perfect" schedule knowledge. This is expected. There is less than a 2.5% probability that the measured difference in the sample means is due to chance alone. In actual waits,

Table 6.6 Statistical Summary of "Perfect" and "Not Perfect" Schedule Knowledge Data.

	"PERFECT"	"NOT PERFECT"
Number of Observations	26	98
Average Wait (seconds EXP 0.2)	2.98	3.14
Standard Deviation (seconds EXP 0.2)	0.303	0.337

F calc = 1.24 ALPHA F = 55%

T calc = -2.32 ALPHA T = 2.5%

CONCLUSION: Significant

interviewed passengers with "perfect" schedule knowledge waited an average of 259 seconds (4:19), while interviewed passengers with "not perfect" schedule knowledge waited an average of 341 seconds (5:41).

Although it is not suprising that passengers with "perfect" schedule knowledge have shorter waits than those with "not perfect" schedule knowledge, the underlying mechanism is not certain for the data collected in this research. Two possibilities exist:

1. The schedules published by Edmonton Transit help passengers predict when buses will arrive at a particular stop.
2. Passengers who know the schedule are more conscious of time, and of timing their arrival with the bus.

Some light may be thrown upon this by analyszing the combined effects of schedule knowledge and experience.

6.3.7 Combined Effect of Schedule Knowledge and Experience

Table 6.7 shows a break down of the numbers and proportions of "experienced" and "not experienced" passengers at a given level of schedule knowledge. Similarly, it shows the number and proportions of "perfect" and "not perfect" schedule knowledge passengers at a given level of experience. The data tend to indicate that the proportion of "perfect" schedule knowledge passengers is independent of experience, and that the proportion of "experienced" passengers is independent of schedule

Table 6.7 Passenger Data by Schedule Knowledge and Experience.

SCHEDULE KNOWLEDGE	EXPERIENCE	FREQUENCY	AVERAGE WAIT	
			(min:sec)	(sec)
"Not Perfect"	"Not Experienced"	9	8:31	238
"Not Perfect"	"Experienced"	89	5:23	167
"Perfect"	"Not Experienced"	3	6:03	130
"Perfect"	"Experienced"	23	4:05	122

Of 112 "experienced" passengers, 23 (21%) have "perfect" schedule knowledge.
Of 12 "not experienced" passengers, 3 (25%) have "perfect" schedule knowledge.

Of 98 "not perfect" schedule knowledge passengers, 89 (91%) are "experienced".
Of 26 "perfect" schedule knowledge passengers, 23 (88%) are "experienced".

knowledge (i.e that schedule knowledge and experience are independent).

If experience and schedule knowledge are independent, a valid method of analysis is to compare passengers according to both their experience and schedule knowledge. The wait time distributions for each of these groups are shown in Figure 6.9. Table 6.7 summarizes the average wait times for each category of combined schedule knowledge and experience.

Comparing the "experienced" passengers, it appears that those with "perfect" schedule knowledge have, on average, shorter waits. However, it appears that experience is the dominant influence for these waits, as the distribution for "experienced" passengers with "not perfect" schedule knowledge is still well skew to the left. For "not experienced" passengers there is little data, but it tends to indicate that there are shorter waits for "perfect" schedule knowledge. It appears that "not experienced" passengers with "not perfect" schedule knowledge arrive randomly, as would be expected.

The data tend to show that schedule knowledge can reduce waits. However, experience appears to be the dominant factor, as passengers without "perfect" schedule knowledge had waits well below those expected for random arrivals. The data also support the notion of providing easily accessable schedule information to passengers. This would likely reduce waits for inexperienced passengers and improve the perceived performance of the bus system for experienced users.

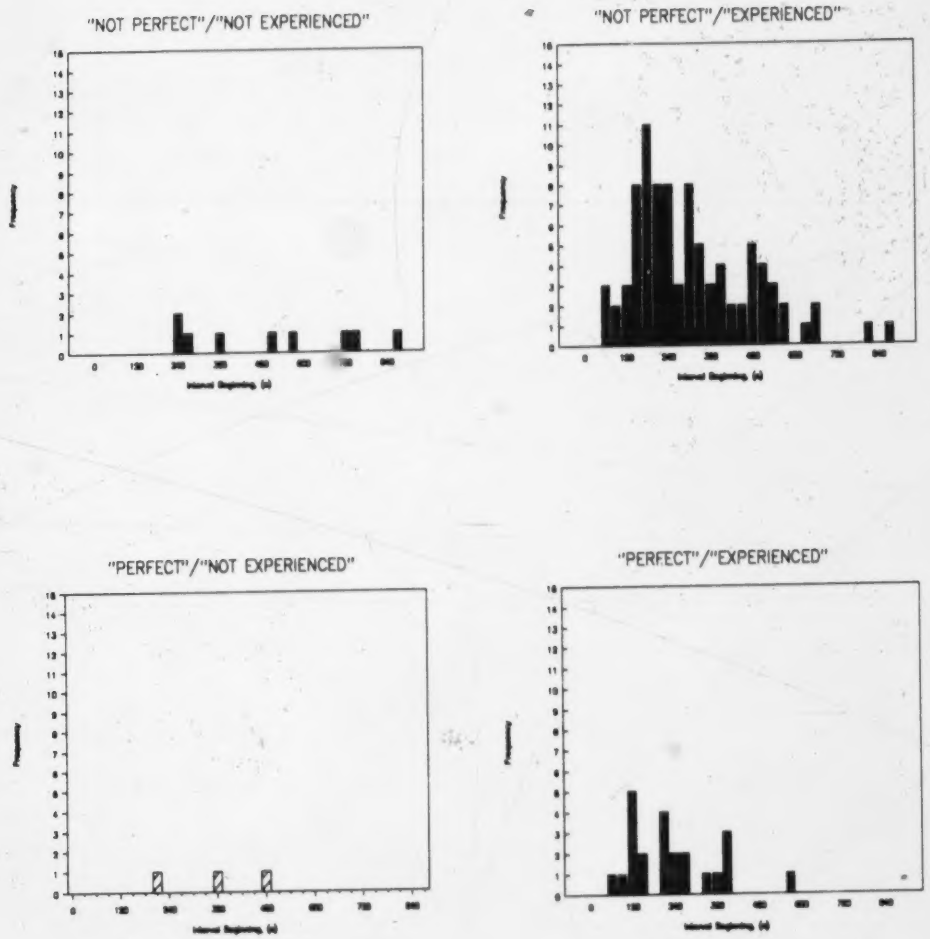


Figure 6.9 Wait Time Distributions for Specified Levels of Experience and Schedule Knowledge.

6.3.8 Effect of Trip Purpose

Most observed trip purposes were either school (66) or work (48). Only 12 shopping, recreation, and "other" trips were observed. These 12 trips were combined to form a new "other" trip purpose category.

Preceeding analyses were based on comparing passengers from two distinct categories. The trip purpose analysis is based on comparing passengers from three distinct trip purpose categories. Thus the previous analysis tools cannot be used directly here, but rather ANOVA is used.

It is hypothesized that trip purpose may effect wait times, as differing trip purposes may have differing levels of importance. For example, the consequences of being late for work may be much more serious than being late for a movie. Thus passengers may assess their risks and behave accordingly. Passengers with higher levels of trip importance may take less risks catching the bus. Thus their wait time distributions should have less variation (i.e. smaller variance).

The results of the ANOVA table are shown in Table 6.8. A tenth root transformation was used for analysis. The level of significance α = 43% indicates that there is little reason to believe that trip purpose has a measureable effect on wait time.

Analysis of residuals is required to confirm the IIDN$(0,\sigma^2)$ assumption (see Appendix A). For this research, the analysis of residuals boils down to checking the

Table 6.8 ANOVA Table for Trip Purpose Categories of Work, School, and "Other".

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES (seconds EXP 0.1)	MEAN SQUARES (seconds EXP 0.1)
Between Groups	2	0.159	0.0080
Within Groups	123	1.16	0.0094

F calc = 0.85 ALPHA F = 43%

CONCLUSION: Not Significant

	WORK	SCHOOL	"OTHER"
NUMBER OF OBSERVATION	48	66	12
AVERAGE WAIT (seconds EXP 0.1)	1.75	1.76	1.79
STANDARD DEVIATION (seconds EXP 0.1)	0.084	0.099	0.128

normality of the overall trip purpose distribution, as well as the distributions for each trip purpose.

It was found that each trip purpose tenth root wait time distribution, as well as the overall trip purpose tenth root wait time distribution, passed the normal distribution tests. The results are summarized in Appendix B.8.

It would seem reasonable to assume that the level of importance of these trips, in descending order, is from Work to School to "Other". As hypothesized, the variance of the wait time distributions for these trips increases as the level of importance decreases (see Table 6.8). However, this trend is not strong enough to produce a statistically significant difference.

Each trip purpose wait time distributions, as well as the overall trip purpose distribution, are shown in Figure 6.10. There are some subtle differences in the distributions. School trips, in comparison to Work trips, tend to have a higher proportion of waits longer than 10 minutes. The "Other" trip distribution appears to be uniform (although its sample size is small) and has a longer average wait. This may reflect a tendency for these trips to be less regular than School or Work trips. This implies that experience may play a role. Only 6 of 12 "Other" trips were "experienced".

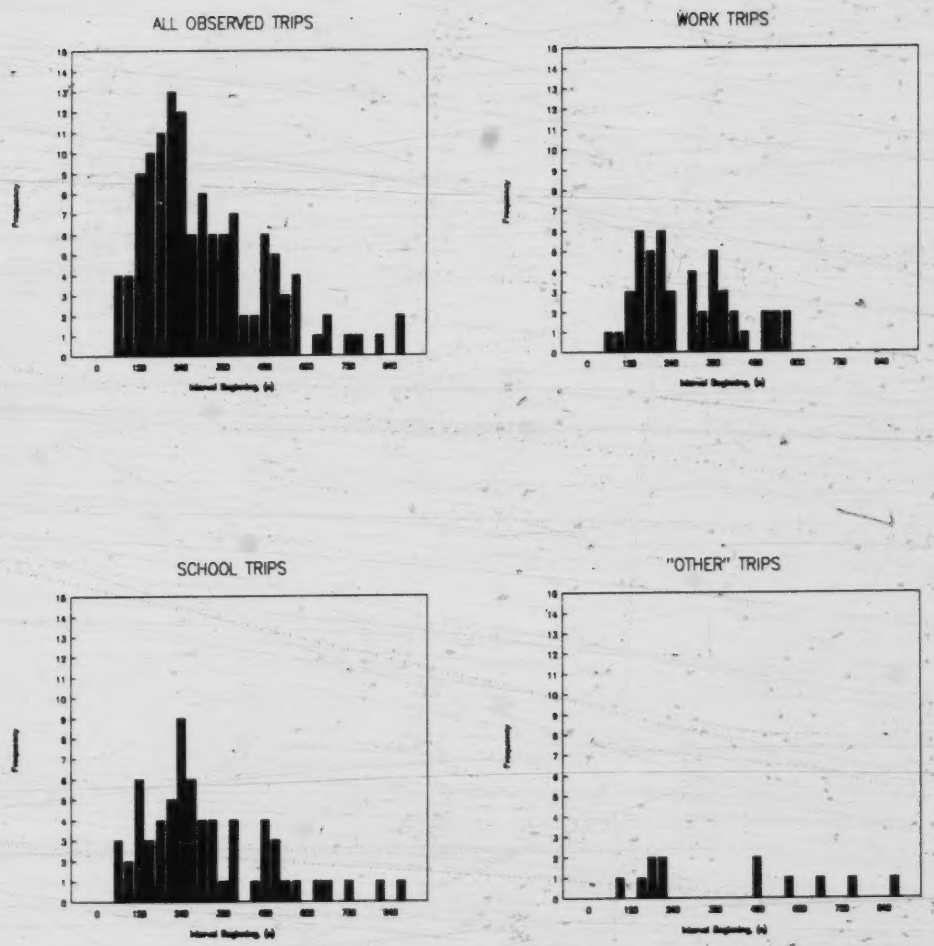


Figure 6.10 Overall and Specific Trip Purpose Wait Time Distributions.

6.4 Summary of Statistical Analysis

The preceeding pages uncovered new findings regarding bus passenger wait time. Following is a summary of those findings:

1. Although no statistical difference was found between wait times measured in "good" versus "bad" weather, it is possible that differences do exist. The expected trends in the data were observed, but were likely not strong due to the small differences in the "good" and "bad" weather observed in this study.
2. Passengers arriving in groups seem to be more sensitive to weather than passengers arriving individually.
3. The level of experience that a passenger has catching a bus at a particular stop in the last seven days has a significant bearing on the wait time for that passenger. "Not experienced" passengers tend to arrive randomly and wait, on average, approximately half the headway. "Experienced" passengers tend to arrive at the end of the headway and have considerably shorter waits. This suggests that separate wait time models could be developed for passengers with different levels of experience. Also, this suggests that ridership elasticities with respect to service frequency may be much higher for infrequent users, as their waits would be more dramatically impacted by a service

frequency change.

4. Passengers with "perfect" schedule knowledge have shorter waits than those with "not perfect" schedule knowledge. Both categories have waits less than half of the headway, suggesting that experience plays a significant role for passengers with "not perfect" schedule knowledge.
5. Schedule knowledge may be more important for "not experienced" passengers. "Experienced" passengers with "not perfect" schedule knowledge typically had waits of less than half the headway.
6. Trip purpose does not seem to have a major role in explaining wait time. School trips tend to have more variation in wait times than work trips, but they essentially do not differ. "Other" trips, such as shopping, recreation, or banking trips, may have longer waits than work and school trips, but again the difference was not significant.

7. Conclusions, Applications and Recommendations

Many new findings regarding factors affecting wait time were discovered in this study. These are summarized in the Conclusion section. The Applications section discusses potential uses of these conclusions. Recommendations are then made as to areas requiring further study, and to continuing research based on this study.

7.1 Conclusions

By way of the objective of this research, several factors affecting wait time were studied. The factors and their effects are summarized below.

7.1.1 Weather

Weather did not have a statistically significant effect on average wait time or the variance of wait time. However, the variation in weather during this study was not large. There were no passenger arrivals during precipitation and temperatures ranged from $+3^{\circ}C$ to $-8^{\circ}C$. The observer often had difficulty classifying the weather.

7.1.2 Groups

Persons arriving in groups did not have statistically significant different average waits from those of individuals. It was thought that they may differ, either because groups must coordinate their pre-bus arrival activities or because groups have an additional utility of

the company of another person.

7.1.3 Groups and Weather

Individuals did not have statistically significant average waits in "good" versus "bad" weather. However, persons in groups did have statistically significant average waits in different weather. Therefore it was concluded that groups are more sensitive to weather conditions than individuals. On "good" weather days, the company of another person may make long waits less annoying. On "bad" weather days, groups show latent learning by better coordinating their bus stop arrival time with the bus's arrival time. Groups were not included in subsequent analysis.

7.1.4 Schedule Knowledge

Passengers who knew the scheduled time that their bus departed the nearest upstream timing point had statistically significant shorter waits than those who did not know. Those who did not know did not arrive randomly, but rather averaged waits less than half the headway. Their experience had helped to reduce their waits. However, the schedule knowledge was still beneficial to those passengers who were frequent users. The potential benefit of schedule knowledge to infrequent users may be large, as their average waits are relatively long. The exact benefit cannot be quantified as the sample size was very small.

Most passengers did not know the scheduled time of their buses. At stops well beyond the timing point, the proportion of such passengers increased sharply.

7.1.5 Experience

Passengers who used the bus one or less times in the previous seven days tended to arrive randomly, with an average wait of about half the headway. More frequent users tended to arrive toward the end of the headway, with an average wait of well less than half the headway. The shapes of these wait time distributions differ fundamentally. Infrequent transit users may have higher ridership elasticities as their waits could be highly impacted by service frequency changes.

7.1.6 Trip Purpose

Three trip puposes were observed: Work, School, and Other. No statistically significant difference was found in the average waits for these trips.

7.2 Applications of Conclusions

7.2.1 Measuring Wait Time

Many transit agencies measure wait times to calibrate models and to evaluate system performance. It would be prudent to take such measurements only during "good" weather, i.e. when the weather is not causing any visible

discomfort to passengers. Alternatively, measurements during both "good" and "bad" weather may be taken, and a correction for "bad" weather data could be found. "Good" weather days would likely best represent typical operating conditions of the system.

7.2.2 Schedule Information

Good schedule information should provide meaningful, accessable information in a concise, easy-to-understand format. The schedule information provided by Edmonton Transit appeared to help reduce some passengers' waiting time. However, most passengers did not know what time the bus they were about to catch was scheduled to depart the nearest upstream timing point. A large potential for further benefits may exist.

One way of providing better schedule information to passengers is to post schedules for every route at each stop. During this study, it was apparent that the majority of passengers were not using the timing points provided by Edmonton Transit to estimate their bus stop arrival time. Frequent bus users would then be more likely to know the scheduled arrival time of the bus at their stop.

Posted schedule information could best benefit infrequent users. These users tend to arrive randomly, thus having relatively long average waits of half the headway. Rohr (1990) showed that persons who take buses less frequently are more likely to overestimate their waiting

time for buses. Ploof (1990) showed that infrequent users are a very large portion of the persons who weekly use transit.

A second method of providing improved schedule information is by providing a phone number for every bus stop in the system, which would give the scheduled departure time of the next bus (or two). Several cities have installed such systems. A telephone schedule information system would be aimed at a large market, and help to reduce some bias that this market would have against transit use.

Another method of improving schedule knowledge for passengers is to provide "Transit Time" - a prominently displayed, highly accurate, reliable, and calibrated set of clocks strategically located throughout the transit network. In Edmonton's case, such clocks could be placed at transit centers where bus routes connect, and at LRT stations with timed connections or high load points. Passengers passing through these locations could calibrate their watches to "Transit Time". Several benefits are possible. Passengers can better time their bus stop arrivals, thus having shorter waits. Passenger perceptions could be improved. If a passenger is late and misses a bus, he is less likely to blame the bus system. If the bus is early, he can legitimately complain to the transit authority, who can then take corrective action. Bus reliability would likely improve.

The "Transit Time" concept was realized by the author when he adjusted his watch to the time broadcast on Edmonton Transit's bus radio system. The author found that when he departed his house at the same time (to the second) that his bus was scheduled to leave the nearest upstream timing point, he arrived at the stop at the same time that the bus arrived. Any wait experienced was due to the bus's late arrival. If the bus was missed, the author knew it was because he was late. In this case, the author combined both experience and schedule knowledge to time his bus stop arrival time.

7.2.3 Wait Time Modelling

Jackson (1977) developed a wait time model where passengers were separated according to their experience. This research supports Jackson's (1977) approach. Separate equations for average wait time could be developed for frequent and for infrequent users. Frequency of use is often asked in fare surveys. Thus model input data are readily available.

Trip purpose does not appear to be a good variable upon which to base a wait time model. Trip purpose may help to explain the frequency of use, but will not explain wait time as well a frequency of use itself.

7.3 Recommendations

Based on this study some continuing research is recommended. A previous researcher suggested that wait times be compared between night and day conditions. Passengers may feel less secure during hours of darkness and consequently time their arrivals more closely. This behavior may be more pronounced in females. These factors were not studied here, but further research could help guide policies with respect to security and lighting of bus stops.

Based on the finding of the passenger experience catching the bus, a new wait time model could be developed. It would use passenger frequency of use as an input. The wait time model output could be used for input into mode split models, as well as to help evaluate the effects of service changes.

Ridership elasticities with respect to headway for frequent and infrequent users could also be researched. This could help model the impacts of bus frequency changes on wait time and on both frequent and infrequent ridership.

The effects of schedule information could be examined. In particular, the effect of posting schedules at stops upon wait times and upon passengers' schedule knowledge should be investigated. Perhaps different levels of schedule information could be posted at different stops, such as giving the departure time of the nearest upstream timing point versus the departure time of the bus at that stop.

The effects of schedule knowledge and experience in this study were limited to one particular headway. Further research could attempt to find differences in wait times of "experienced" or "perfect" schedule knowledge users in differing headways.

The effect of weather requires futher study. It is still thought that the day to day weather may have a significant impact on the day to day average wait times observed. However, stronger differences in the weather may be required. Also, a better method for classifying weather may help. In addition to the day to day effects of weather, seasonal effects of weather could also be studied. A "good" summer weather day may have different average waits as compared to a "good" winter weather day.

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Appendix A: ANOVA - Theory and Procedure

A.1 Introduction

"ANOVA" is an abbreviation for the statistical analysis method called "ANalysis Of VAriance". It is used to compare more than two sample means, where several "treatments" have been randomly allocated to the "experimental material". In this research the "experimental material" is wait time. Passenger trip purpose is the "treatment".

This appendix discusses the theory and procedure of ANOVA. It borrows heavily from Chapter 6 of Box, et al (1978). For a more detailed discussion of ANOVA, the reader is referred to this book.

A.2 Producing an ANOVA Table

ANOVA theory assumes that the data can be treated as random samples from k normal populations. Each population has the same variance σ^2 and differ, if at all, in their means only.

Each observation in the total population of observations is viewed as being a sum of three components:

A grand average component

A treatment deviation component - i.e. the difference between a particular trip purpose's average wait time and the grand average of all trip purpose observations

A residual (within treatment) component - i.e. the difference between the mean wait time for a particular

trip purpose and a specific observed wait time for that trip purpose

This breakdown is illustrated by the example data in Figure A.1. Although this example is taken from Box, et al (1978) and represents blood coagulation times, it can be thought of as wait time data.

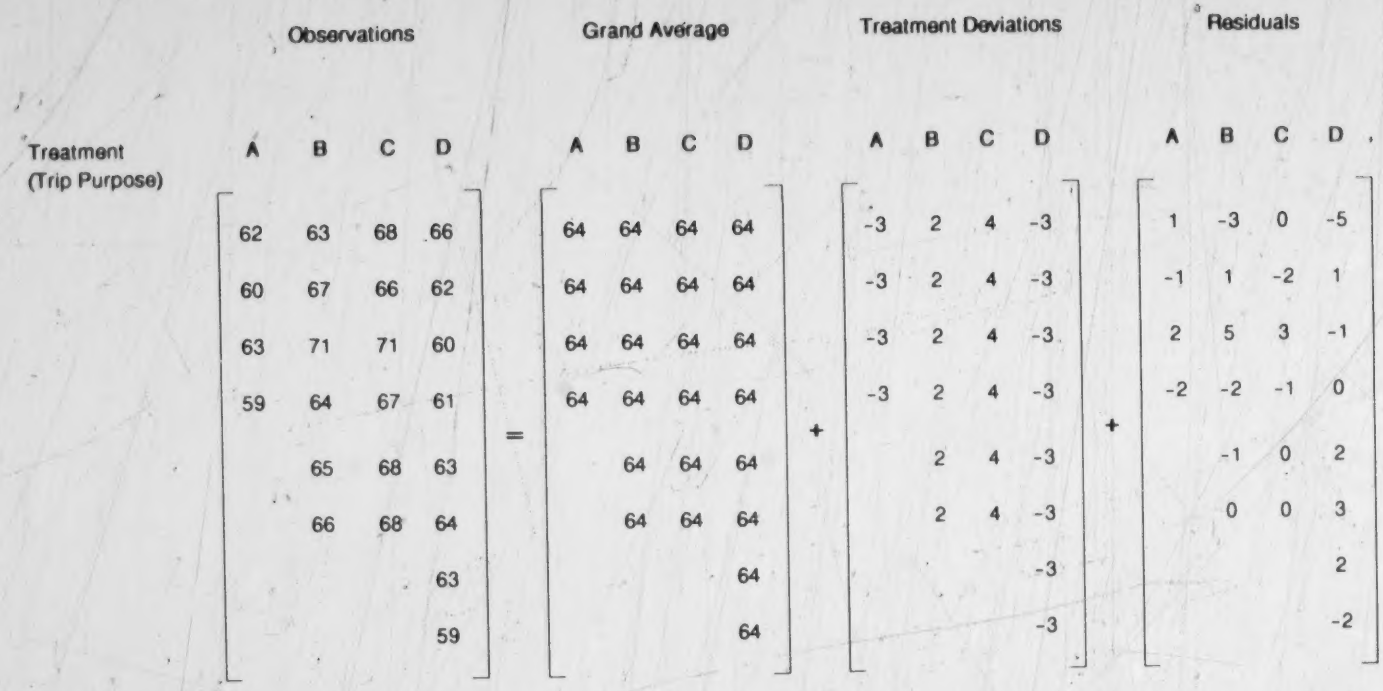
Each column in each vector in Figure A.1 represents observations from a particular trip purpose. Below each vector is its name. The component summation stated at the beginning of this section can be expressed mathematically as:

$$Y = \bar{A} + T + R$$

Below each vector's name is its sum of squares. These are found by summing the square of each element in the vector. Below each vector's sum of squares are its degrees of freedom. These are found by considering the mathematical constraints imposed on each vector.

The information contained in these vectors is expressed more compactly in tabular form, as shown in Figure A.2. Here, each observation is shown but the treatment and overall averages are written only once.

Finally, the information in the previous two figures is expressed in an even more compact form by using an ANOVA table. This is shown in Figure A.3. The ANOVA table is the objective of an ANOVA analysis. For the ANOVA table shown in Figure A.3, the overall average has been discarded. This statistic is only needed when comparing to another known



Vector Name	Y	=	A	+	T	+	R
Sum of Squares	98,644	=	98,304	+	228	+	112
Degrees of Freedom	24	=	1	+	3	+	20

Figure A.1 ANOVA's three components of each observation

	Treatment (Trip Purpose)			
	A	B	C	D
Residuals (within – Treatment Deviations)	1	-3	0	-5
	-1	1	-2	1
	2	5	3	-1
	-2	-2	-1	0
		-1	0	2
		0	0	3
				2
				-2
Deviations of Individual Treatment Averages from Grand Average	-3	2	4	-3
Treatment Averages	61	66	68	61
Grand Average	64			

Figure A.2 A More Compact Form of Expressing the Vector Information.

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square
Between Treatments	S_T	ν_t	$(s_T)^2$
Within Treatments	S_R	ν_R	$(s_R)^2$
Total About the Grand Average	S_D	ν_D	$(s_D)^2$

and: $S_D = S_T + S_R$

$\nu_D = \nu_T + \nu_R$

Figure A.3 The ANOVA Table.

overall average from another set of observations.

The contents of the ANOVA table can now be examined. The pricipal items of interest are the sources of variation and the mean square.

A.3 Sources of Variation

A.3.1 Variation Within Treatments

Each trip purpose (treatment) may have some variation associated with it, called variation within treatments. Since it is assumed that each trip purpose's data has some variation, an estimate of the true overall population variance σ^2 is found by calculating the within-treatment mean square:

$$s_R^2 = \frac{S_R}{N - K}$$

$$= \sum_{t=1}^{k} \sum_{t=1}^{n_t} \frac{(y_{ti} - \bar{y}_t)^2}{N - K}$$

where:

y_{ti} = i^{th} observation of the t^{th} treatment

$\bar{y}_t$ = mean of the t^{th} treatment observations

N = total number of overall observations

K = number of treatments

S_R^2 = within-treatment sum of squares

n_t = number of observations for the i^{th} treatment

In words, the within-treatment mean square is found by

squaring the differences between each trip purpose's mean with each particular observation for that trip purpose, then dividing by the number of degrees of freedom. The degrees of freedom are the total number of observations less the number of trip purposes.

A.3.2 Variation Between Treatments

A second estimate of the true population variance σ^2 is obtained from the variation of each trip purpose's average wait time about the grand average. It is given by the Between-Treatment Mean Square:

$$s_T^2 = \frac{\sum_{t=1}^{k} n_t(\bar{y}_t - \bar{\bar{y}})^2}{K - 1}$$

where:

$\bar{\bar{y}}$ = grand average of all data

other variables as defined previously

In words, the Between-Treatment Mean Square is found by squaring the difference between each trip purpose's average wait time and the grand average, weighting this square by the number of observations for that trip purpose, summing these for all trip purposes, and then dividing by the number of degrees of freedom. The degrees of freedom are the number of trip purposes less one.

This second estimate of σ^2 is true if there are no real differences between treatment means. If the treatment means

do vary, s_T^2 will be inflated relative to σ^2. This is because s_T^2 represents the intrinsic variation σ^2 plus variations from treatment to treatment. Therefore, if there are differences between treatment means, s_T^2 will be greater than σ^2.

A.4 Diagnostic Checking of the Basic Model

Before the ANOVA table is analyzed, diagnostic checks of the basic model must be made so that the underlying assumptions of the ANOVA procedure are satisfied.

The ANOVA table illustrated above is strictly a mathematical procedure. The relations between the various vectors and their sum of squares are true for any data set. ANOVA is relevant because it links observations and the various decompositions with the underlying parameters of the sampled populations. It is only relevant if the data are random samples from k normal populations having the same variance but possibly different means.

Therefore, a model can be written as:

$$y_{ti} = \eta_t + \epsilon_{ti}$$

where:

η_t = true population mean for the t^{th} treatment

ϵ_{ti} = errors that are IIDN$(0,\sigma^2)$, that is independently and identically distributed according to a normal distribution with a mean of zero and an unknown but fixed variance σ^2

If this model is true, then s_R^2 and $\bar{y}_1, \bar{y}_2, \ldots, \bar{y}_k$, would

be sufficient statistics for σ^2 and $\bar{\eta}_1$, $\bar{\eta}_2$, . . ., $\bar{\eta}_k$, the only parameters of the model.

If the IIDN$(0,\sigma^2)$ assumption is correct, then after the statistics s_R^2 and $\bar{y}_1$, $\bar{y}_2$, . . ., $\bar{y}_k$, are calculated no further information remains in the original data and therefore the residuals and original data can be ignored. Attention could then concentrate entirely on the interpretation of these statistics. However, further checks of the data are necessary. The data may contain information not allowed for in the assumed mathematical model and thus not revealed by the associated ANOVA table. These checks consist mainly of an analysis of the residuals.

A.5 Analysis of Residuals

Discrepancies between a tentative model and the data can be detected by studying the residuals $y_{ti} - \bar{y}_{ti}$ ($\bar{y}_{ti}$ is the expected value for treatment t, assuming the model is correct, i.e. the mean of the t^{th} treatment's observations), the elements of vector $\bar{R}$. These residuals are the quantities remaining after the systematic contributions of the assumed model (here, the contributions of the treatment averages) are removed.

If the model's assumptions are true it is expected that, apart from restrictions imposed by the analysis itself (for example, the sum of each treatment's residuals equals zero), the residuals vary randomly. If the residuals contain unexplained systematic tendancies, then the model may be in

error. Therefore as an automatic preliminary procedure to further statistical analysis, the table of residuals is studied. Routine discrepancies are described below, but other abnormalities may exist.

A.5.1 Distribution of Residuals

A frequency distribution plot of all residuals is made. If the IIDN$(0,\sigma^2)$ assumption is true, the distribution should appear as approximately normal with a mean of zero. Small samples may appear bad, but it is not indicative of any underlying cause. When gross abnormalities occur explanations should be sought.

A.5.2 Abnormalities Associated with Particular Treatments

Residuals for a particular treatment may be abnormal. Therefore each treatment's residuals are plotted on a frequency distribution diagram. It is analysed as above.

A.5.3 Relation Between Size of Residuals and the Expected Value of Response

If the mathematical model is correct, the residuals are unrelated to the levels of any known variable. They should be unrelated to the value of the response itself. This is the assumption as used for the F-test, where it is assumed that the variance is not a function of the level of the mean. Thus the residuals $y_{ti} - \bar{y}_{ti}$ are plotted against estimated values of $\bar{y}_{ti}$.

Figure A.4 provides an example of such a plot. If the variance increases as the value of the response increases, the plot would be funnel shaped.

A.6 Use of the Anova Table

Once the model $y_{ti} = \eta_t + \epsilon_{ti}$ does not contain any obvious inadequacies (after examination of the residuals), the ANOVA table can be studied. The ANOVA table provides a basis for a formal test of the null hypothesis that the treatment means are all equal (i.e. $\eta_1 = \eta_2 = . \; . \; . = \eta_k$).

If the null hypothesis were true and the $IIDN(0,\sigma^2)$ assumption held for the errors, then s_T^2/s_R^2 would follow an F distribution with ν_t and ν_t degrees of freedom (see Figure A.5). If the observed F value is greater than the F value at the selected significance level, then the null hypothesis is rejected and there may be real differences between the treatment means.

This analysis is sometimes called an "one-way ANOVA" or "single-classification ANOVA", because the data are classified in only one way, namely, by treatment.

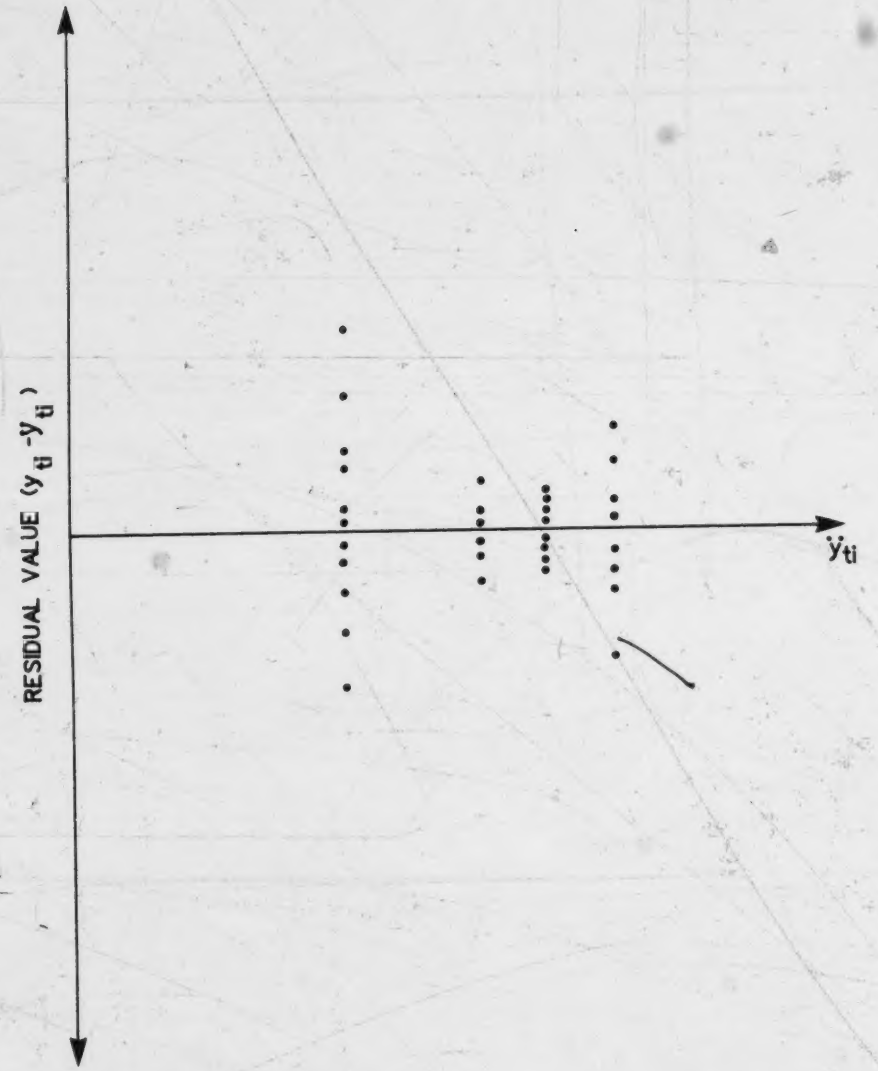


Figure A.4 Plot of Residuals Against the Measured Treatment Means.

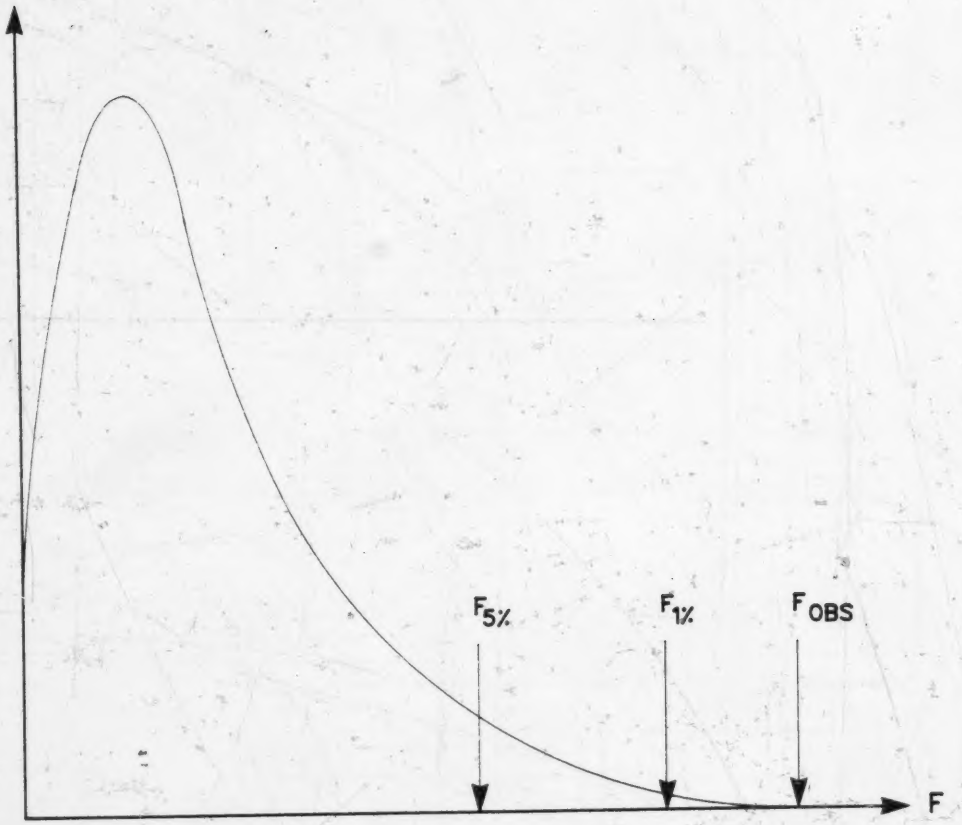


Figure A.5 F Distribution.

Appendix B: Normal Distribution Tests

B.1 "Good" and "Bad" Weather Wait Time Distributions

Wait time distributions for passengers arriving in "Good" and "Bad" weather are shown in Figure B.1. Both appear to be severely skew to the left. In the interest of establishing a frame of reference for succeeding tests, the B-S test is presented.

Table B.1 shows the B-S test results for each distribution, and indicates that neither is normal.

The "Good" and "Bad" weather wait time distributions both fail both normal distribution tests.

B.2 "Good" and "Bad" Weather Square Root Wait Time Distributions

A square root tranformation (i.e. $f(X)=x^{0.5}$) yields normally distributed data. Both distributions are shown in Figure B.2. Both have a "blip" at the beginning. These represent passengers with zero wait time, and were included so as to retain as much information as possible. Disregarding the "blips", both distributions appear normal. Table B.2 shows B-S test results. Both distributions pass the B-S criteria.

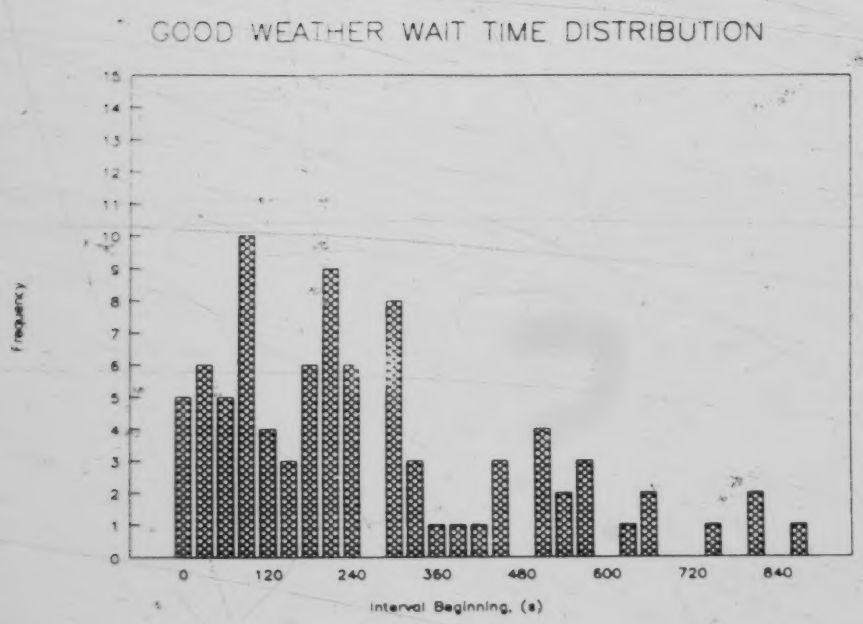
It is concluded that both distributions are normal.

Table B.1 B-S Tests for Wait Time Distributions of Passengers Arriving in "Good" and "Bad" Weather.

	"GOOD"	"BAD"
Number of Observations	87	114
Skewness	0.970	1.041
Kurtosis	0.338	1.139
B-S CALCULATED	14.1	26.8
B-S TABULATED (ALPHA)	4.28 (5%)	4.32 (5%)
Conclusion	Reject	Reject

Table B.2 B-S Tests for Square Root Wait Time Distributions of Passengers Arriving in "Good" and "Bad" Weather.

	"GOOD"	"BAD"
Number of Observations	87	114
Skewness	-0.009	-0.039
Kurtosis	-0.324	-0.115
B-S CALCULATED	0.382	0.092
B-S TABULATED (ALPHA)	3.11 (10%)	3.22 (10%)
Conclusion	Accept	Accept



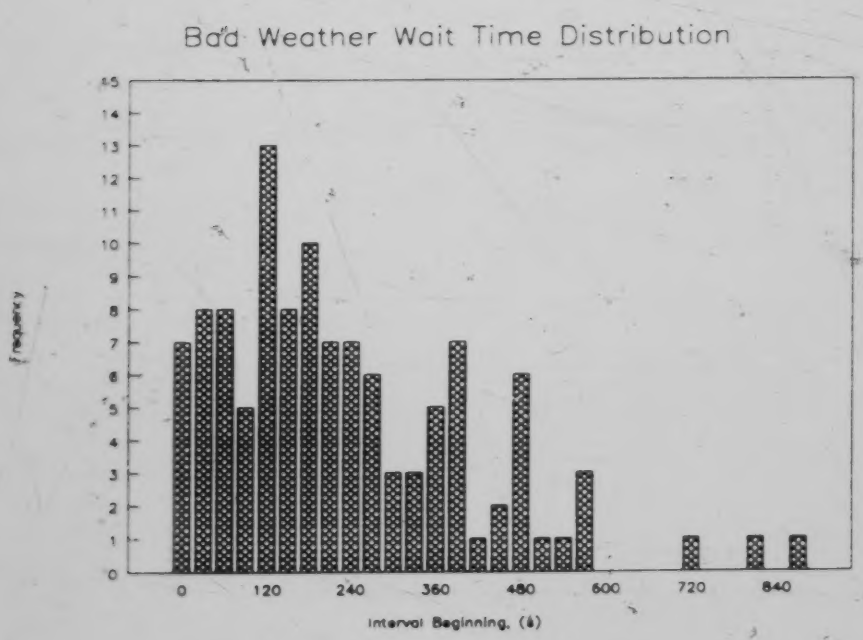
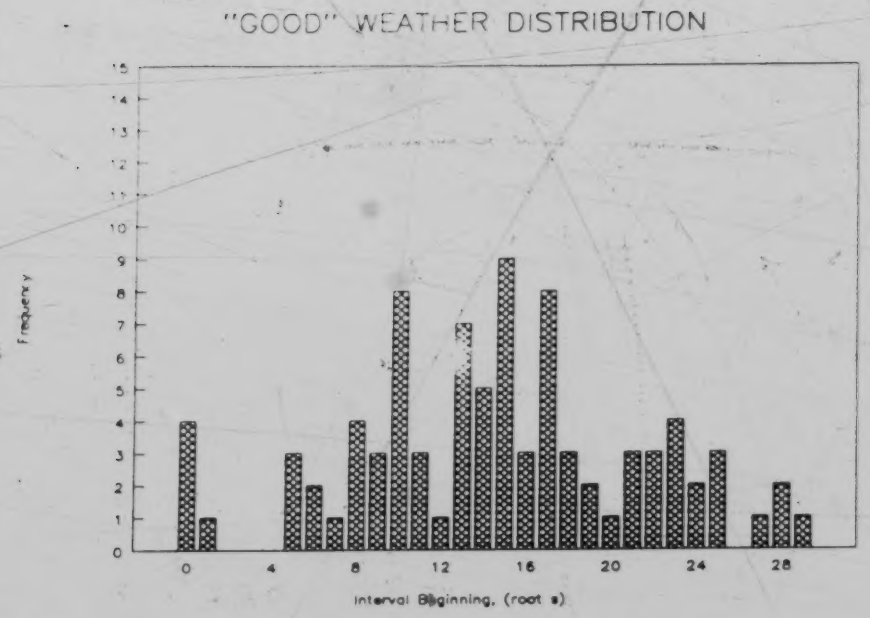


Figure B.1 Wait Time Distribution for Passengers Arriving in "Good" and "Bad" Weather.



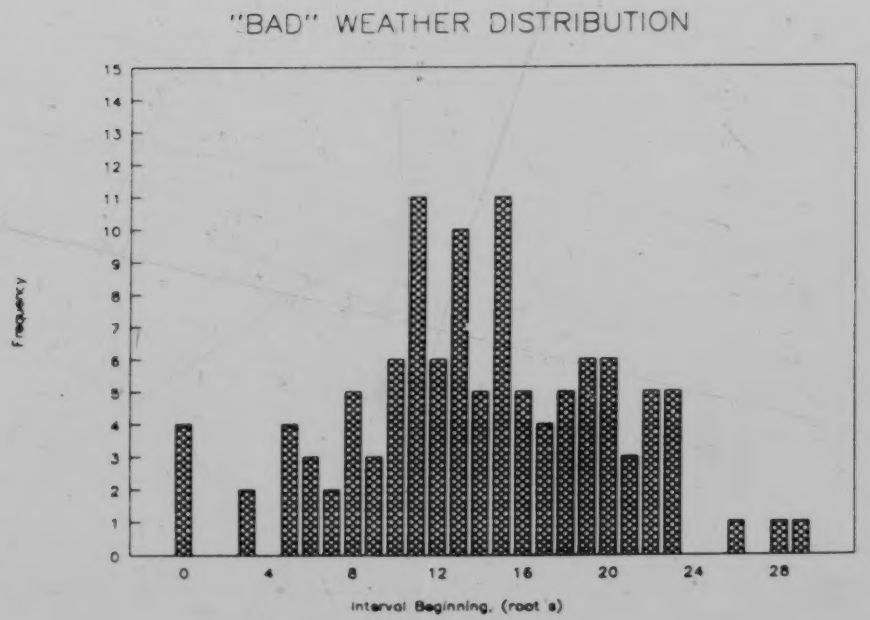


Figure B.2 Square Root Wait Time Distribution for Passengers Arriving in "Good" and "Bad" Weather.

B.3 Group and Individual Arrival Distributions

A square root tranformation (i.e. $f(y)=x^{0.5}$) was used to obtain normally distributed data. Figure B.3 show the distributions. B-S test results are given in Table B.3.

It is concluded that the data are normally distributed.

B.4 Arrival Distributions of Individuals in "Good" and "Bad" Weather

A square root transformation (i.e. $f(x)=x^{0.5}$) was employed to obtain normally distributed data. Figure B.4 show the resulting distributions. Table B.4 provides B-S test results.

It is concluded that the data are normally distributed.

B.5 "Experienced" and "Not Experienced" Distributions

A two-fifths root transfomation (i.e. $f(x)=x^{0.4}$) was used to obtain normally distributed data. The distributions are shown in Figure B.5. Table B.5 shows B-S test results for several transformations. The two-fifths root transformation provides the lowest B-S statistic for the "Not Experienced" distribution, while still passing the "Experienced" distribution.

B.6 "Perfect" and "Not Perfect" Schedule Knowledge Distributions

A fifth root transformation (i.e. $f(x)=x^{0.2}$) was used to obtain normally distributed data. The distributions are

Table B.3 B-S Tests for Square Root Wait Time Distributions of Passengers Arriving in Groups and Individually.

	INDIVIDUALS	GROUPS
Number of Observations	174	12
Skewness	-0.009	0.918
Kurtosis	-0.324	1.69
B-S CALCULATED	0.382	1.69
B-S TABULATED (ALPHA)	3.11 (10%)	2.13 (10%, N=20)
Conclusion	Accept	Borderline, Small Sample

Table B.4 B-S Tests for Square Root Wait Time Distributions of Individuals Arriving in "Good" and "Bad" Weather.

	"GOOD"	"BAD"
Number of Observations	75	99
Skewness	-0.025	-0.191
Kurtosis	-0.350	-0.084
B-S CALCULATED	0.39	0.63
B-S TABULATED (ALPHA)	3.09 (10%)	3.14 (10%)
Conclusion	Accept	Accept

Table B.5 B-S Tests for Several Transformations of the "Experienced" and "Not Experienced" Passenger Wait Distributions.

TRANSFORMATION	SKEWNESS	KURTOSIS	B-S CALCULATED	B-S TABULATED (ALPHA)	CONCLUSION
"Experienced" Passengers, N = 122					
f(x)=(x)EXP 0.2	0.065	-0.405	0.92	3.22 (10%)	Accept
f(x)=(x)EXP 0.3	0.180	-0.392	1.44	3.22 (10%)	Accept
f(x)=(x)EXP 0.4	0.311	-0.334	2.53	3.22 (10%)	Accept
f(x)=(x)EXP 0.5	0.430	-0.233	3.70	4.31 (5%)	Reject
f(x)=(x)EXP 0.6	0.549	-0.088	6.17	4.31 (5%)	Reject
f(x)=(x)EXP 0.7	0.667	0.101	9.10	4.31 (5%)	Reject
f(x)=(x)EXP 0.8	0.784	0.333	13.1	4.31 (5%)	Reject
"Not Experienced" Passengers, N = 13					
f(x)=(x)EXP 0.2	-0.436	-0.085	0.416	2.13 (10%)*	Accept
f(x)=(x)EXP 0.3	-0.301	-0.339	0.259	2.13 (10%)*	Accept
f(x)=(x)EXP 0.4	-0.173	-0.537	0.222	2.13 (10%)*	Accept
f(x)=(x)EXP 0.5	-0.055	-0.684	0.260	2.13 (10%)*	Accept
f(x)=(x)EXP 0.6	0.055	-0.786	0.341	2.13 (10%)*	Accept
f(x)=(x)EXP 0.7	0.158	-0.848	0.444	2.13 (10%)*	Accept
f(x)=(x)EXP 0.8	0.254	-0.876	0.555	2.13 (10%)*	Accept

* for N = 20

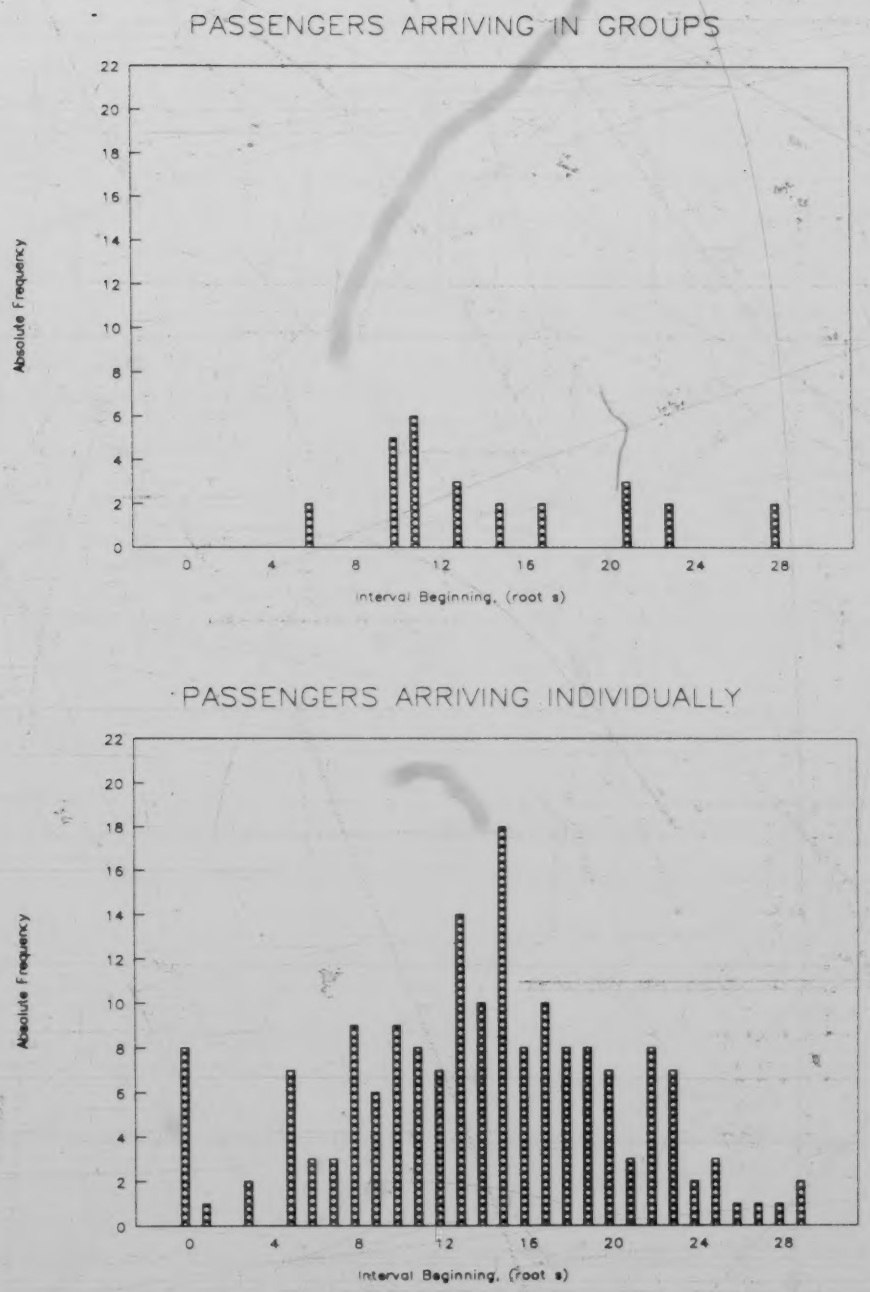


Figure B.3 Square Root Wait Time Distribution for Passengers Arriving in Groups and Individually.

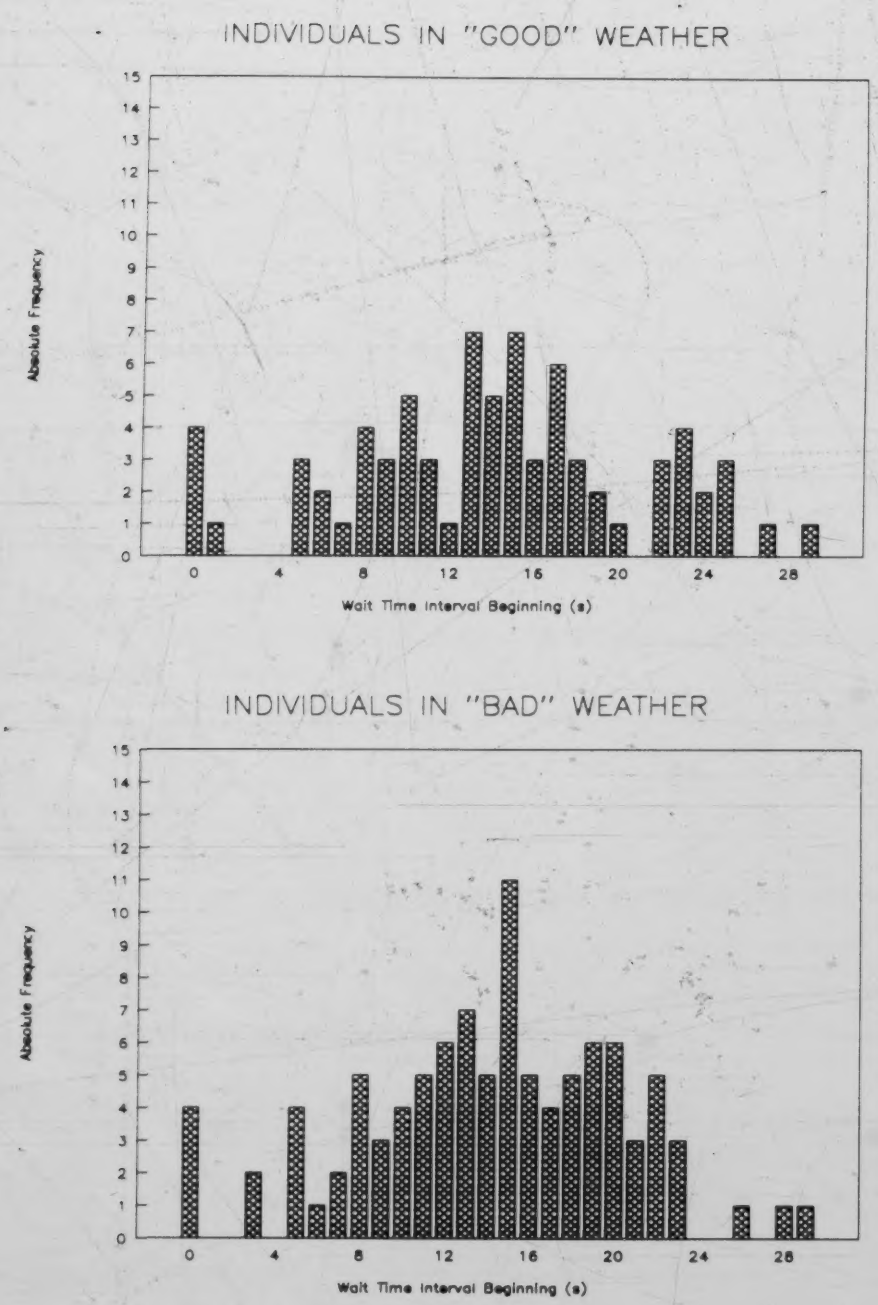
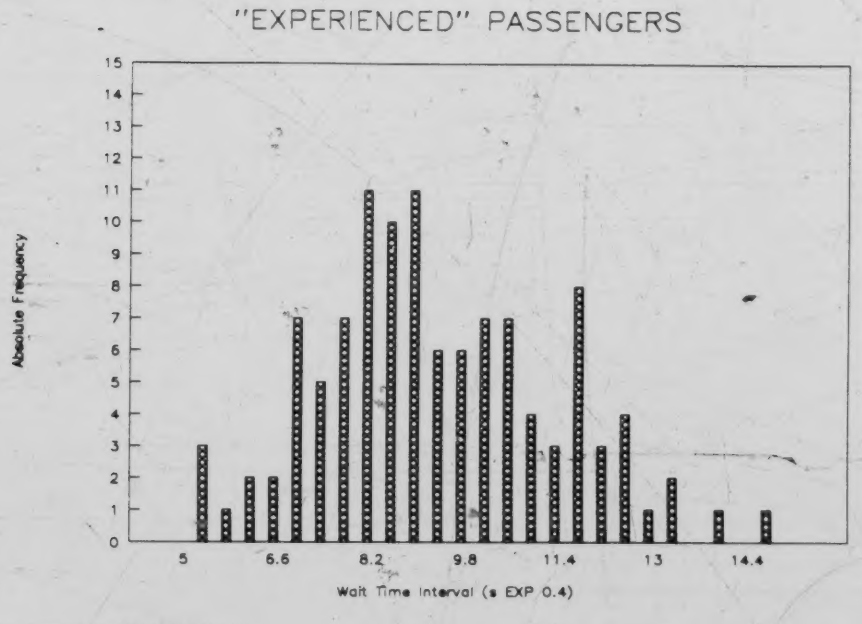


Figure B.4 Square Root Wait Time Distribution for Individuals Arriving in "Good" and "Bad" Weather.



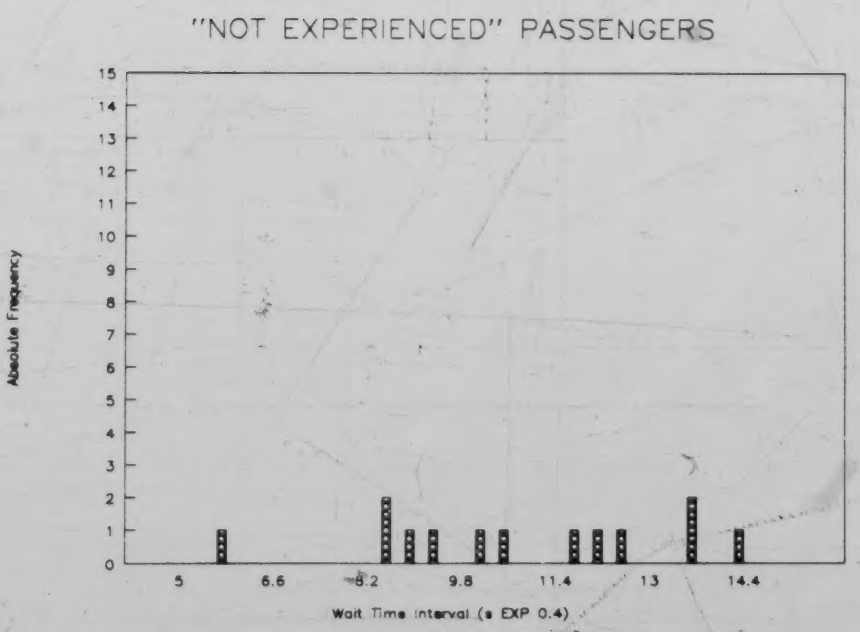


Figure B.5 Two-Fifths Root Wait Time Distribution for "Experienced" and "Not Experienced" Passengers.

shown in Figure B.6. Table B.6 shows B-S test results for several transformations. The fifth root transformation provides the lowest B-S statistic for the "Perfect" schedule knowledge distribution, while still passing the "Not Perfect" distribution.

B.7 Work, School, "Other", and Overall Trip Purpose Distributions

A tenth root transfomation (i.e $f(x)=x^{0.1}$) was employed to obtain normally distributed data. The distributions are shown in Figure B.7. The distributions appear to be normal, except for the "Other" trips (Figure B.16). It appears bimodal, but the data set is small. Further examination of this apparent grouping showed no trend with respect to schedule knowledge, experience, stated trip purpose or weather. Table B.7 shows B-S test results for several transformations. The tenth root transformation provides the lowest B-S statistic for all trip classifications except school trips, where a fifth root transformation is best. All trip classifications comfortably pass the B-S test.

It is concluded that the tenth root wait time distributions for the Overall trip purpose data, as well as the School and Work trips, are normally distributed. The "Other" trip distribution is assumed to be normal, as too little data is present for a definite conclusion.

Table B.6 B-S Tests for Several Transformations of the "Perfect" and "Not Perfect" Schedule Knowledge Passenger Wait Distributions.

TRANSFORMATION	SKEWNESS	KURTOSIS	B-S CALCULATED	B-S TABULATED (ALPHA)	CONCLUSION
"Not Perfect" Schedule Knowledge, N = 98					
f(x)=(x)EXP 0.1	-0.052	-0.386	0.653	3.14 (10%)	Accept
f(x)=(x)EXP 0.2	0.075	-0.444	0.897	3.14 (10%)	Accept
f(x)=(x)EXP 0.3	0.197	-0.456	1.48	3.14 (10%)	Accept
f(x)=(x)EXP 0.4	0.316	-0.425	2.37	3.14 (10%)	Accept
f(x)=(x)EXP 0.5	0.431	-0.355	3.55	4.29 (5%)	Reject
f(x)=(x)EXP 0.6	0.542	-0.249	5.05	4.29 (5%)	Reject
f(x)=(x)EXP 0.7	0.652	-0.108	6.99	4.29 (5%)	Reject
f(x)=(x)EXP 0.8	0.759	0.065	9.43	4.29 (5%)	Reject
"Perfect" Schedule Knowledge, N = 26					
f(x)=(x)EXP 0.1	-0.189	-0.444	0.368	2.24 (10%)	Accept
f(x)=(x)EXP 0.2	-0.079	-0.522	0.322	2.24 (10%)	Accept
f(x)=(x)EXP 0.3	0.028	-0.564	0.348	2.24 (10%)	Accept
f(x)=(x)EXP 0.4	0.132	-0.571	0.429	2.24 (10%)	Accept
f(x)=(x)EXP 0.5	0.234	-0.546	0.560	2.24 (10%)	Accept
f(x)=(x)EXP 0.6	0.334	-0.491	0.745	2.24 (10%)	Accept
f(x)=(x)EXP 0.7	0.432	-0.408	0.989	2.24 (10%)	Accept
f(x)=(x)EXP 0.8	0.528	-0.298	1.30	2.24 (10%)	Accept

Table B.7 B-S Tests for Several Transformations of the Trip Purpose Data.

TRANSFORMATION	SKEWNESS	KURTOSIS	B-S CALCULATED	B-S TABULATED (ALPHA)	CONCLUSION
All Trip Purposes, N = 126					
f(x)=(x)EXP 0.05	-0.101	-0.401	1.06	3.31 (10%)	Accept
f(x)=(x)EXP 0.1	-0.036	-0.430	0.998	3.31 (10%)	Accept
f(x)=(x)EXP 0.2	0.091	-0.450	1.24	3.31 (10%)	Accept
f(x)=(x)EXP 0.3	0.216	-0.434	1.97	3.31 (10%)	Accept
f(x)=(x)EXP 0.4	0.338	-0.372	3.13	3.31 (10%)	Borderline
f(x)=(x)EXP 0.5	0.458	-0.270	4.79	4.34 (5%)	Reject
Work Trips, N = 48					
f(x)=(x)EXP 0.1	-0.185	-0.583	0.954	2.86 (10%)	Accept
f(x)=(x)EXP 0.2	-0.088	-0.696	1.03	2.86 (10%)	Accept
f(x)=(x)EXP 0.3	0.003	-0.776	1.20	2.86 (10%)	Accept
f(x)=(x)EXP 0.4	0.090	-0.827	1.43	2.86 (10%)	Accept
f(x)=(x)EXP 0.5	0.172	-0.853	1.69	2.86 (10%)	Accept
School Trips, N = 66					
f(x)=(x)EXP 0.1	-0.104	-0.278	0.332	3.02 (10%)	Accept
f(x)=(x)EXP 0.2	0.037	-0.305	0.271	3.02 (10%)	Accept
f(x)=(x)EXP 0.3	0.177	-0.285	0.568	3.02 (10%)	Accept
f(x)=(x)EXP 0.4	0.314	-0.220	1.22	3.02 (10%)	Accept
f(x)=(x)EXP 0.5	0.449	-0.112	2.25	3.02 (10%)	Accept
"Other" Trips, N = 12					
f(x)=(x)EXP 0.1	-0.121	-1.420	1.04	2.13 (10%)*	Accept
f(x)=(x)EXP 0.2	-0.047	-1.494	1.12	2.13 (10%)*	Accept
f(x)=(x)EXP 0.3	0.023	-1.54	1.19	2.13 (10%)*	Accept
f(x)=(x)EXP 0.4	0.090	-1.562	1.24	2.13 (10%)*	Accept
f(x)=(x)EXP 0.5	0.154	-1.562	1.27	2.13 (10%)*	Accept

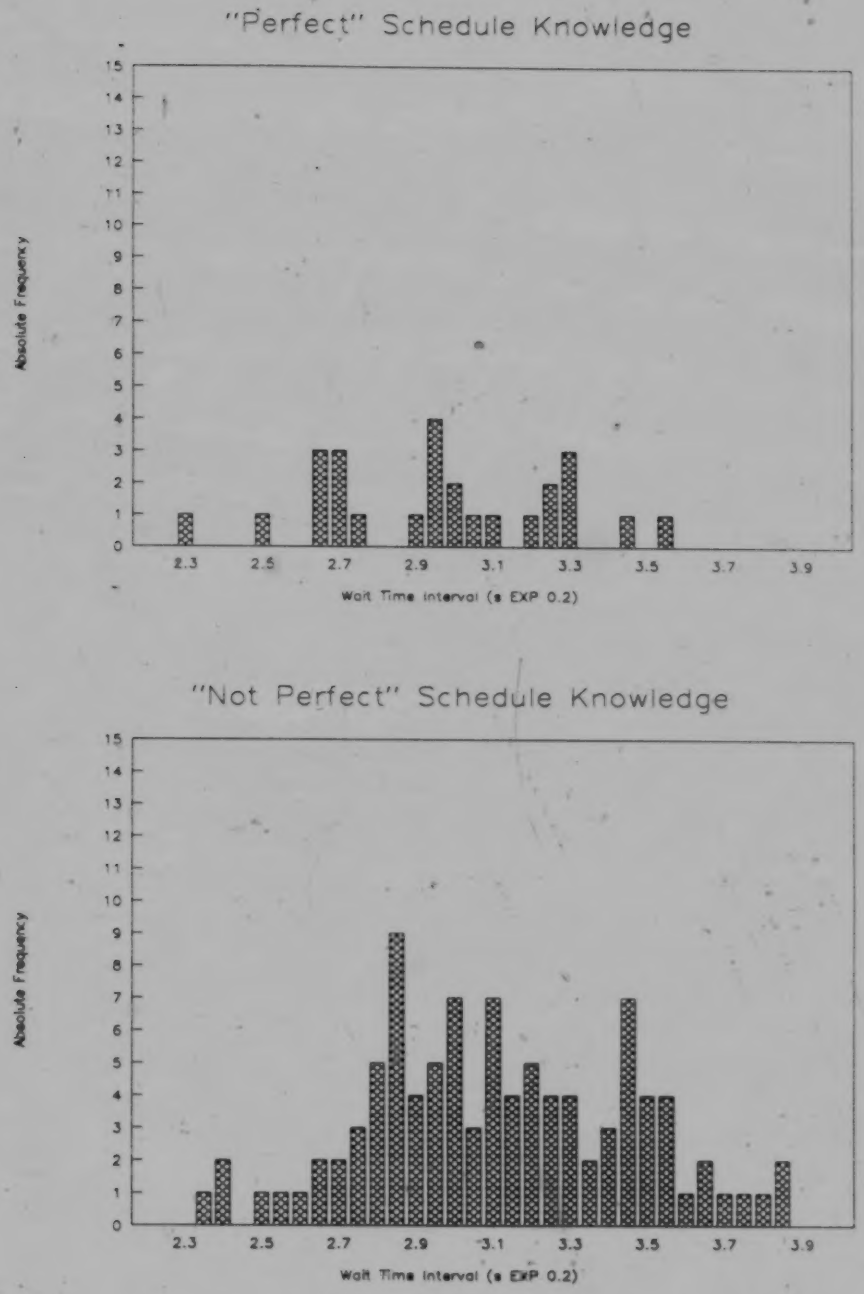


Figure B.6 Fifth Root Wait Time Distribution for "Perfect" and "Not Perfect" Schedule Knowledge Passengers.

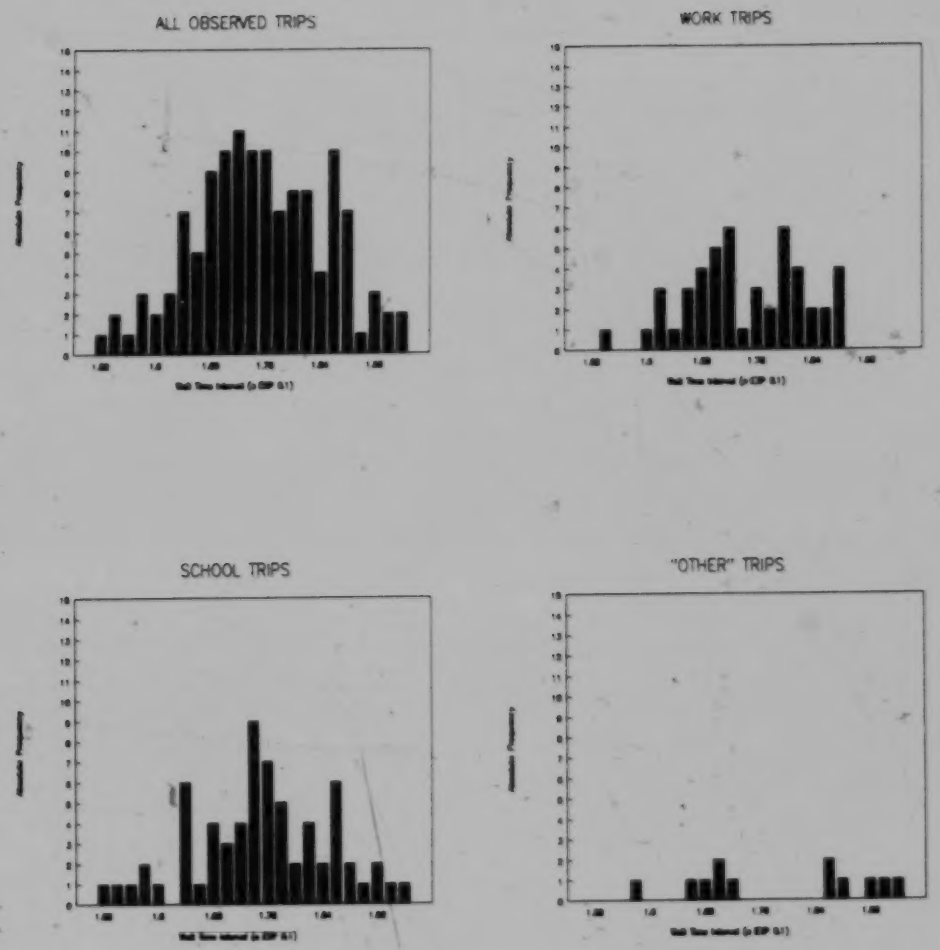


Figure B.7 Tenth Root Wait Time Distribution of Overall and Specified Trip Purpose Data.

Appendix C: Data File for SPSS^{X} Runs

The following pages list the data file used as input into the SSPS^{X} runs. When an analysis of group arrivals was done where each group was treated as a single observation, a new data file was created. It eliminated all but one of each of the group arrivals.

Listing of DATA BUSS at 17:40:01 on AUG 8, 1990 for CC1D=DIA4 on DA=TAMTS

RAW DATA: BUS PASSENGER WAIT TIME STUDY, 1988

DATA CODES:
WEATHER: 0=GOOD, 1=OK, 2=BAD,
12=OK OR BAD, 10=OK OR GOOD
TRIP: 1=WORK, 2=SCHOOL, 3=SHOPPING,
4=RECREATION, 5=OTHER, -9=NA
EXPERIENCE: NO. CORRESPONDS TO NO. OF
TIMES CATCHING BUS AT THAT
STOP IN THE LAST WEEK, -9=NA
SCHEDULE KNOWLEDGE: 1=CORRECT,
2=WITHIN 1 MIN, 3=GUESSED
WRONG, 4=ANSWERED "NO", -9=NA

	DATE	ROUTE	WEATHER	NO. IN GROUP	TRIP	EXP	SCHED	WAIT
21	SAT OCT 29	29	0	1	4	0	1	230
22	SAT OCT 29	29	0	1	4	4	4	220
23	SAT OCT 29	29	0	1	5	0	4	585
24	MON OCT 31	30	0	1	1	5	3	75
25	MON OCT 31	30	0	1	2	5	3	105
26	MON OCT 31	30	0	1	-9	-9	-9	100
27	MON OCT 31	30	0	1	-9	-9	-9	95
28	MON OCT 31	30	0	1	1	0	4	530
29	MON OCT 31	30	0	1	1	5	2	305
30	MON OCT 31	30	0	1	-9	-9	-9	300
31	MON OCT 31	30	0	1	1	5	4	200
32	MON OCT 31	30	0	1	2	5	1	140
33	MON OCT 31	30	0	1	2	5	1	70
34	MON OCT 31	30	0	1	2	5	4	630
35	MON OCT 31	30	0	1	2	5	4	515
36	MON OCT 31	30	0	1	2	5	4	515
37	MON OCT 31	30	0	1	1	5	4	350
38	MON OCT 31	30	0	1	2	5	4	260
39	MON OCT 31	30	0	1	2	5	4	260
40	MON OCT 31	30	0	1	-9	-9	-9	195
41	MON OCT 31	30	0	1	2	5	1	100
42	MON OCT 31	30	0	1	-9	-9	-9	100
43	MON OCT 31	30	0	1	-9	-9	-9	30
44	MON OCT 31	30	0	1	2	14	2	195
45	MON OCT 31	30	0	3	2	-9	-9	110
46	MON OCT 31	30	0	3	2	-9	-9	110
47	MON OCT 31	30	0	3	2	-9	-9	110
48	MON OCT 31	30	0	1	-9	-9	-9	1
49	MON OCT 31	30	0	1	1	4	1	570
50	MON OCT 31	30	0	1	2	5	4	225
51	MON OCT 31	30	0	1	2	5	4	175
52	MON OCT 31	30	0	1	1	5	3	175
53	MON OCT 31	30	0	1	-9	-9	-9	175
54	MON OCT 31	30	0	1	-9	-9	-9	85
55	MON OCT 31	18	0	1	5	1	4	870
56	MON OCT 31	18	0	1	1	6	3	315
57	MON OCT 31	18	0	1	-9	-9	-9	1
58	MON OCT 31	18	0	1	4	0	3	755

Listing of DATA.BUS88 at 17.40.03 on AUG 5, 1990 for CCid=GSA4 on UALTAMTS

59	MON	OCT	31	18	0	1	2	5	3	590
60	MON	OCT	31	18	0	1	1	5	3	300
61	MON	OCT	31	18	0	1	3	2	3	185
62	MON	OCT	31	18	0	1	-9	-9	-9	5
63	MON	OCT	31	18	0	1	2	5	4	665
64	MON	OCT	31	18	0	1	2	5	4	395
65	TUE	NOV	1	43	0	1	1	5	4	425
66	TUE	NOV	1	43	0	1	1	5	2	540
67	TUE	NOV	1	43	0	1	-9	-9	-9	1
68	TUE	NOV	1	43	0	1	2	6	1	220
69	TUE	NOV	1	43	0	1	1	5	1	245
70	TUE	NOV	1	43	0	1	1	7	1	130
71	TUE	NOV	1	43	0	1	1	0	3	365
72	TUE	NOV	1	43	0	1	-9	-9	-9	45
73	SAT	NOV	5	29	0	1	2	1	3	240
74	MON	NOV	7	39	2	1	1	5	2	240
75	MON	NOV	7	39	2	1	2	5	4	70
76	MON	NOV	7	39	2	1	2	5	4	300
77	MON	NOV	7	39	2	1	2	5	1	290
78	MON	NOV	7	39	2	1	2	5	3	175
79	MON	NOV	7	39	2	1	2	5	4	135
80	MON	NOV	7	39	2	1	2	5	1	435
81	MON	NOV	7	39	2	1	2	0	4	280
82	MON	NOV	7	39	2	1	2	1	2	275
83	MON	NOV	7	39	2	1	1	5	4	215
84	MON	NOV	7	39	2	1	-9	-9	-9	235
85	MON	NOV	7	39	2	1	-9	-9	-9	215
86	MON	NOV	7	39	2	1	-9	-9	-9	215
87	MON	NOV	7	39	2	1	-9	-9	-9	155
88	MON	NOV	7	39	2	1	-9	-9	-9	155
89	MON	NOV	7	39	2	1	-9	-9	-9	95
90	MON	NOV	7	39	2	1	-9	-9	-9	95
91	MON	NOV	7	39	2	1	2	5	4	495
92	MON	NOV	7	39	2	1	2	5	4	135
93	MON	NOV	7	39	2	1	-9	-9	-9	45
94	MON	NOV	7	39	2	1	2	5	4	230
95	MON	NOV	7	39	2	1	2	5	4	230
96	MON	NOV	7	39	2	1	2	5	3	220
97	MON	NOV	7	5	2	1	2	4	3	875
98	MON	NOV	7	5	2	1	5	6	4	200
99	MON	NOV	7	5	2	1	2	5	1	140
100	MON	NOV	7	5	2	1	3	3	4	495
101	MON	NOV	7	5	2	1	3	3	4	160
102	TUE	NOV	8	43	2	1	1	5	4	530
103	TUE	NOV	8	43	2	1	1	5	4	415
104	TUE	NOV	8	43	2	1	1	5	4	415
105	TUE	NOV	8	43	2	1	1	5	4	195
106	TUE	NOV	8	43	2	1	1	5	4	220
107	TUE	NOV	8	43	2	1	5	0	1	490
108	TUE	NOV	8	43	2	1	2	5	4	400
109	TUE	NOV	8	43	2	1	1	5	1	370
110	TUE	NOV	8	43	2	1	-9	-9	-9	70
111	TUE	NOV	8	43	2	1	-9	-9	-9	45
112	TUE	NOV	8	43	2	1	2	5	4	480
113	TUE	NOV	8	43	2	1	2	5	3	335
114	TUE	NOV	8	43	2	1	2	5	4	195
115	TUE	NOV	8	43	2	1	-9	-9	-9	180
116	TUE	NOV	8	43	2	1	-9	-9	-9	400

Listing of DATA BUSES at 17:40:03 on AUG 5, 1990 for CCid=8544 on uALTAMTS

117	TUE	NOV	8	43	2	1	1	5	3	360
118	TUE	NOV	8	43	2	1	2	5	1	250
119	TUE	NOV	8	43	2	1	1	5	4	170
120	TUE	NOV	8	43	2	2	-9	-9	-9	140
121	TUE	NOV	8	43	2	2	-9	-9	-9	140
122	TUE	NOV	8	43	2	1	1	6	1	390
123	TUE	NOV	8	43	2	1	2	5	4	390
124	TUE	NOV	8	43	2	1	-9	-9	-9	70
125	TUE	NOV	8	43	2	1	1	1	1	370
126	TUE	NOV	8	43	2	1	1	6	1	170
127	MON	NOV	14	30	12	1	2	5	1	145
128	MON	NOV	14	30	12	1	2	3	2	405
129	MON	NOV	14	30	12	1	2	15	1	285
130	MON	NOV	14	30	12	1	2	0	2	285
131	MON	NOV	14	30	12	1	1	4	1	225
132	MON	NOV	14	30	12	1	1	5	3	475
133	MON	NOV	14	30	12	1	2	5	4	325
134	MON	NOV	14	30	12	1	2	5	1	270
135	MON	NOV	14	30	12	1	2	0	4	250
136	MON	NOV	14	30	12	1	2	3	4	140
137	MON	NOV	14	30	12	1	-9	-9	-9	15
138	MON	NOV	14	30	12	1	-9	-9	-9	85
139	MON	NOV	14	30	12	2	-9	-9	-9	140
140	MON	NOV	14	30	12	2	-9	-9	-9	140
141	MON	NOV	14	30	12	1	-9	-9	-9	55
142	MON	NOV	14	30	12	1	2	5	3	505
143	MON	NOV	14	30	12	1	2	7	4	495
144	MON	NOV	14	30	12	1	2	5	4	350
145	MON	NOV	14	30	12	1	2	5	4	470
146	MON	NOV	14	30	12	1	2	12	4	290
147	MON	NOV	14	30	12	1	2	5	4	290
148	MON	NOV	14	30	12	1	-9	-9	-9	85
149	MON	NOV	14	30	12	2	-9	-9	-9	45
150	MON	NOV	14	30	12	2	-9	-9	-9	45
151	MON	NOV	14	30	12	1	-9	-9	-9	25
152	MON	NOV	14	30	12	1	-9	-9	-9	245
153	MON	NOV	14	30	12	2	-9	-9	-9	110
154	MON	NOV	14	30	12	2	-9	-9	-9	110
155	MON	NOV	14	30	12	1	2	1	4	720
156	MON	NOV	14	30	12	2	2	2	3	575
157	MON	NOV	14	30	12	2	2	2	3	575
158	MON	NOV	14	30	12	1	2	4	4	385
159	MON	NOV	14	5	12	1	1	7	3	575
160	MON	NOV	14	5	12	2	-9	-9	-9	125
161	MON	NOV	14	5	12	2	-9	-9	-9	125
162	MON	NOV	14	5	12	1	2	3	4	565
163	MON	NOV	14	5	12	1	2	5	4	230
164	TUE	NOV	15	3	1	1	-9	-9	-9	50
165	TUE	NOV	15	3	1	1	1	5	4	150
166	TUE	NOV	15	3	1	1	-9	-9	-9	1
167	TUE	NOV	15	3	1	1	1	5	4	200
168	TUE	NOV	15	3	1	1	1	5	4	165
169	TUE	NOV	15	3	1	1	-9	-9	-9	135
170	TUE	NOV	15	3	1	1	-9	-9	-9	15
171	TUE	NOV	15	3	1	1	1	6	3	200
172	TUE	NOV	15	29	2	1	2	4	4	505
173	TUE	NOV	15	29	2	1	1	2	2	250
174	TUE	NOV	15	29	2	1	-9	-9	-9	35

Listing of DATA.BUS86 at 17:40:03 on AUG 5, 1990 for CC1d=GSA4 on UALTAMTS

175	TUE	NOV	15	29	2	1	2	5	4	85
176	MON	NOV	21	30	12	1	1	5	4	230
177	MON	NOV	21	30	12	1	2	4	4	215
178	MON	NOV	21	30	12	1	1	-9	-9	125
179	MON	NOV	21	30	12	1	2	5	4	300
180	MON	NOV	21	30	12	1	-9	-9	-9	30
181	MON	NOV	21	30	12	1	1	5	4	175
182	MON	NOV	21	30	12	1	2	5	3	155
183	MON	NOV	21	30	12	1	-9	-9	-9	80
184	MON	NOV	21	30	12	1	1	5	4	195
185	MON	NOV	21	30	12	1	1	5	4	135
186	MON	NOV	21	30	12	1	2	5	3	120
187	MON	NOV	21	30	12	1	1	5	1	340
188	MON	NOV	21	30	12	1	2	5	3	255
189	MON	NOV	21	30	12	1	2	5	4	255
190	MON	NOV	21	30	12	1	2	5	1	235
191	MON	NOV	21	30	12	3	-9	-9	-9	180
192	MON	NOV	21	30	12	3	-9	-9	-9	180
193	MON	NOV	21	30	12	3	-9	-9	-9	180
194	TUE	NOV	22	43	12	1	1	5	1	235
195	TUE	NOV	22	43	12	1	2	5	3	265
196	TUE	NOV	22	43	12	1	-9	-9	-9	115
197	TUE	NOV	22	43	12	1	2	5	3	280
198	TUE	NOV	22	43	12	1	-9	-9	-9	1
199	TUE	NOV	22	43	12	1	2	5	4	810
200	TUE	NOV	22	43	12	1	1	4	3	440
201	TUE	NOV	22	43	12	1	-9	-9	-9	65
202	TUE	NOV	22	43	12	1	-9	-9	-9	1
203	TUE	NOV	22	43	12	1	1	5	3	370
204	TUE	NOV	22	43	12	1	1	2	4	115
205	TUE	NOV	22	43	12	1	-9	-9	-9	115
206	TUE	NOV	22	43	12	1	-9	-9	-9	35
207	TUE	NOV	22	43	12	1	2	5	4	320
208	TUE	NOV	22	43	12	1	2	5	1	150
209	TUE	NOV	22	43	12	1	-9	-9	-9	75
210	TUE	NOV	22	43	12	1	-9	-9	-9	1
211	MON	NOV	28	30	0	1	1	5	4	550
212	MON	NOV	28	30	0	1	1	5	3	310
213	MON	NOV	28	30	0	1	1	5	3	235
214	MON	NOV	28	30	0	1	1	5	3	245
215	MON	NOV	28	30	0	1	2	6	4	335
216	MON	NOV	28	30	0	1	2	5	4	335
217	MON	NOV	28	30	0	1	2	5	4	185
218	MON	NOV	28	30	0	1	-9	-9	-9	115
219	MON	NOV	28	30	0	1	-9	-9	-9	50
220	MON	NOV	28	30	0	1	-9	-9	-9	75
221	MON	NOV	28	30	0	1	-9	-9	-9	40
222	MON	NOV	28	30	0	1	-9	-9	-9	35
223	MON	NOV	28	30	0	1	-9	-9	-9	1
224	MON	NOV	28	30	0	1	2	7	3	265
225	MON	NOV	28	30	0	1	1	5	3	215
226	MON	NOV	28	30	0	1	2	7	1	145
227	TUE	NOV	29	43	0	1	2	7	4	200
228	TUE	NOV	29	43	0	2	1	3	4	320
229	TUE	NOV	29	43	0	2	2	3	4	320
230	TUE	NOV	29	43	0	1	2	2	4	80
231	TUE	NOV	29	43	0	1	-9	-9	-9	35
232	TUE	NOV	29	43	0	1	5	0	-9	95

Listing of DATA.BJS88 at 17:40:03 on AUG 5, 1990 for CCId=GS44 on DALTAMTS

233	TUE	NOV	29	43	0	2	2	5 4	810
234	TUE	NOV	29	43	0	2	2	5 4	810
235	TUE	NOV	29	43	0	1	2	5 4	665
236	TUE	NOV	29	43	0	1	2	5 4	515
237	TUE	NOV	29	43	0	3	2	5 4	455
238	TUE	NOV	29	43	0	3	2	5 4	455
239	TUE	NOV	29	43	0	3	2	5 4	455
240	TUE	NOV	29	43	0	1	2	5 4	305
241	TUE	NOV	29	43	0	2	2	5 4	230
242	TUE	NOV	29	43	0	2	2	5 4	230
243	TUE	NOV	29	43	0	1	-9	-9 -9	230
244	TUE	NOV	29	43	0	1	-9	-9 -9	130

Appendix D: SSPS^{X} Runs

The following pages list the source file containing the SSPS^{X} commands used to execute each data analysis. The runs are in reverse chronological order.

Listing of RUN SPSS at 20:34:40 on SEP 23, 1990 for CCid=GS44 on UALTAMTS

```
comment
comment      F-test and T-test for all each trip purpose
                 against each other.
                 Sunday, Nov. 17, 1989.

             Using PT1 Transformation.

             NOTE: GROUPS ARE NOT INCLUDED!

DATA LIST FILE='DATA.BUS88(21,244)'
    /route 16-17 ngroup 31 trip 37-38 wait 53-55
select if (trip ne -9)
select if (route ne 39)
select if (ngroup eq 1)
recode trip (3,4,5=3)
COMPUTE PT1=(WAIT)**0.1
T-test groups=trip(1,2)/variable=PT1
T-test groups=trip(1,3)/variable=PT1
T-test groups=trip(2,3)/variable=PT1
finish
comment
comment      Oneway ANOVA. Trip purpose is treatment.
                 trips 3, 4, & 5 combined as trip=3.
                 Sunday, November 17, 1989.

             Using PT1 Transformation.

             NOTE: GROUPS ARE NOT INCLUDED!

DATA LIST FILE='DATA.BUS88(21,244)'
    /route 16-17 ngroup 31 trip 37-38 wait 53-55
select if (trip ne -9)
select if (route ne 39)
select if (ngroup eq 1)
recode trip (3,4,5=3)
COMPUTE pt1=(WAIT)**0.1
oneway pt1 by trip(1,3)
    /format=labels
    /contrast=-1 1 0
    /contrast=-1 0 1
    /contrast=0 -1 1
    /statistics=descriptives
sort cases by trip
split file by trip
frequencies vars=pt1
    /statistics=mean mode skewness kurtosis default
finish
comment
comment      Search for a better transformation for
                 Trip Purspose data (Overall data).
             Sun, November 17, 1989


DATA LIST FILE='DATA.BUS88(21,244)'
    /route 16-17 ngroup 31 trip 37-38 wait 53-55
select if (route ne 39)
select if (trip ne -9)
select if (ngroup eq 1)
```

```
Listing of RUN.SPSS at 20:34:40 on SEP 23, 1990 for CCid=GSA4 on UALTAMTS

     recode trip (3,4,5=3)
     COMPUTE pt05=(WAIT)**0.05
     COMPUTE pt1=(WAIT)**0.1
     COMPUTE pt2=(WAIT)**0.2
     COMPUTE pt3=(WAIT)**0.3
     COMPUTE pt4=(WAIT)**0.4
     COMPUTE pt5=(WAIT)**0.5
     descriptives variables=all
          /statistics=default kurtosis skewness
     finish
     comment
     comment      Search for a better transformation for
                      Trip Purspose data.
                  Sat, November 17, 1989


     DATA LIST FILE='DATA.BUS88(21,244)'
          /route 16-17 ngroup 31 trip 37-38 wait 53-55
     select if (route ne 39)
     select if (trip ne -9)
     select if (ngroup eq 1)
     recode trip (3,4,5=3)
     COMPUTE pt1=(WAIT)**0.1
     COMPUTE pt2=(WAIT)**0.2
     COMPUTE pt3=(WAIT)**0.3
     COMPUTE pt4=(WAIT)**0.4
     COMPUTE pt5=(WAIT)**0.5
     sort cases by trip
     split file by trip
     descriptives variables=pt1 to pt5
          /statistics=default kurtosis skewness
     finish
     comment
     comment      F-test and T-test for "perfect" and "imperfect"
                      schedule knowledge, WITHOUT GROUPS.

                  PT2 TRANSFORMATION
                  AUGUST 21, 1989

     DATA LIST FILE='DATA.BUS88(21,244)'
          /route 16-17 ngroup 31 sched 46-47 wait 53-55
     select if (sched ne -9)
     select if (route ne 39)
     select if (ngroup eq 1)
     recode sched (2,3,4=0)
     COMPUTE PT2=(WAIT)**0.2
     t-test groups=sched(1)/variables=pt2
     sort cases by sched
     split file by sched
     frequencies vars=pt2
          /statistics=mean mode kurtosis skewness default
     finish
     comment
     comment
               October 15, 1989

               F-test and t-test for experienced vs inexperienced
                        riders, for four definitions of inexperienced.
```

Listing of RUN SPSS at 20:34:40 on SEP 23, 1990 for CCid=GSA4 on UALTAMTS

```
                        riders

                        - one or more trips per week
                        - two or more trips per week
                        - three or more trips per week
                        - four or more trips per week

                   GROUPS ARE NOT INCLUDED!
                   USING PT4 TRANSFORMATION

     data list file='data.bus88(21,244)'
          /route 16-17 ngroup 31 exp 43-44 wait 53-55
     select if (exp ne -9)
     select if (route ne 39)
     select if (ngroup eq 1)
     compute PT4=(wait)**0.4
     t-test groups=exp(4)/variables=pt4
     t-test groups=exp(3)/variables=pt4
     t-test groups=exp(2)/variables=pt4
     t-test groups=exp(1)/variables=pt4
     recode exp(4 thru 20=4)
     sort cases by exp
     split file by exp
     frequencies vars=pt4
          /statistics=mean mode skewness kurtosis default
     finish
     comment
     comment      Search for a better transformation for
                      Schedule Knowledge data.
                  Sunday, October 15, 1989


     DATA LIST FILE='DATA.BUS88(21,244)'
          /route 16-17 ngroup 31 sched 46-47 wait 53-55
     select if (route ne 39)
     select if (sched ne -9)
     select if (ngroup eq 1)
     recode sched (2,3,4=0)
     COMPUTE pt1=(WAIT)**0.1
     COMPUTE pt2=(WAIT)**0.2
     COMPUTE pt3=(WAIT)**0.3
     COMPUTE pt4=(WAIT)**0.4
     COMPUTE pt6=(WAIT)**0.6
     COMPUTE pt7=(WAIT)**0.7
     COMPUTE pt8=(WAIT)**0.8
     sort cases by sched
     split file by sched
     descriptives variables=pt1 to pt8
          /statistics=default kurtosis skewness
     finish
     comment
     comment      Search for a better transformation for
                      Experience data.
                  Sunday, October 15, 1989


     DATA LIST FILE='DATA.BUS88(21,244)'
          /route 16-17 ngroup 31 exp 43-44 wait 53-55
```

Listing of RUN.SPSS at 20:34:40 on SEP 23, 1990 for CCid=GS44 on UALTAMTS

```
175     select if (route ne 39)
176     select if (exp ne -9)
177     select if (ngroup eq 1)
178     recode exp (0,1=0) (2 thru 15=5)
179     COMPUTE pt2=(WAIT)**0.2
180     COMPUTE pt3=(WAIT)**0.3
181     COMPUTE pt4=(WAIT)**0.4
182     COMPUTE pt6=(WAIT)**0.6
183     COMPUTE pt7=(WAIT)**0.7
184     COMPUTE pt8=(WAIT)**0.8
185     sort cases by exp
186     split file by exp
187     descriptives variables=pt2 to pt8
188          /statistics=default kurtosis skewness
189     finish
190     comment
191     comment      Search for a better transformation for
192                      individual versus group arrivals.
193                      Each group member is treated as a
194                      single arrival.
195                  Saturday, October 7, 1989
196
197
198     DATA LIST FILE='DATA.BUS88(21,244)'
199        /route 16-17 ngroup 31 wait 53-55
200     select if (route ne 39)
201     recode ngroup (2,3=2)
202     COMPUTE pt2=(WAIT)**0.2
203     COMPUTE pt3=(WAIT)**0.3
204     COMPUTE pt4=(WAIT)**0.4
205     COMPUTE pt6=(WAIT)**0.6
206     COMPUTE pt7=(WAIT)**0.7
207     COMPUTE pt8=(WAIT)**0.8
208     sort cases by ngroup
209     split file by ngroup
210     descriptives variables=pt2 to pt8
211          /statistics=default kurtosis skewness
212     finish
213     comment
214     comment      T-test and F-test for groups in "bad" versus
215                      "good" weather, and for individuals in "bad"
216                      versus "good" weather.  Each group member
217                      is treated as a single arrival.
218                  Sunday, October 1, 1989
219
220
221     DATA LIST FILE='DATA.BUS88(21,244)'
222        /route 16-17 weather 21-22 ngroup 31 wait 53-55
223     select if (route ne 39)
224     recode weather (1,12=2)
225     recode ngroup (2,3=2)
226     COMPUTE rtwait=sqrt(WAIT)
227     sort cases by ngroup
228     split file by ngroup
229     t-test groups=weather(2)/variables=rtwait
230     finish
231     comment
232     comment      T-test and wait and square root distributions
```

Listing of RUN.SPSS at 20:34:40 on SEP 23, 1990 for CCid=GSA4 on UALTAMTS

```
233                    for Groups versus Individuals, with "good"
234                    and "bad" weather splits.  Each group member
235                    is treated as a single arrival
236                Sunday, October 1, 1989
237
238
239     DATA LIST FILE='DATA.BUS88(21,244)'
240         /route 16-17 weather 21-22 ngroup 31 wait 53-55
241     select if (route ne 39)
242     recode weather (1,12=2)
243     recode ngroup (2,3=2)
244     COMPUTE rtwait=sqrt(WAIT)
245     sort cases by weather
246     split file by weather
247     t-test groups=ngroup(2)/variables=rtwait
248     sort cases by weather ngroup
249     split file by weather ngroup
250     frequencies vars=wait rtwait
251          /statistics=mean mode skewness kurtosis default
252     finish
253     comment
254     comment      'T-test and wait and square root distributions
255                    for Groups versus Individuals, with each group
256                    member treated as a single arrival.
257                Sunday, October 1, 1989
258
259
260     DATA LIST FILE='DATA.BUS88(21,244)'
261         /route 16-17 ngroup 31 wait 53-55
262     select if (route ne 39)
263     COMPUTE rtwait=sqrt(WAIT)
264     t-test groups=ngroup(2) variables=rtwait
265     recode ngroup (2,3=2)
266     sort cases by ngroup
267     split file by ngroup
268     frequencies vars=wait rtwait
269          /statistics=mean mode skewness kurtosis default
270     finish
271     comment
272     comment ,    Wait and Root wait distributions for each schedule
273                    knowledge (including -9), with experience
274                    level breakdowns.  Sunday, sept. 23/89.
275
276                NOTE: GROUPS ARE NOT INCLUDED!
277
278     DATA LIST FILE='DATA.BUS88(21,244)'
279         /route 16-17 ngroup 31 exp 43-44 sched 46-47 wait 53-55
280     select if (route ne 39)
281     select if (ngroup eq 1)
282     recode sched (2,3,4=0)
283     recode exp (0,1=0)
284     recode exp(2 thru 20=5)
285     COMPUTE rtwait=sqrt(WAIT)
286     sort cases by sched exp
287     split file by sched exp
288     frequencies vars=wait rtwait
289          /statistics=mean mode skewness kurtosis default
290     finish
```

Listing of RUN SPSS at 20:34:40 on SEP 23, 1990 for CCid=GSA4 on UALTAMTS

```
291     comment
292     comment      Wait and Root wait distributions for each trip
293                      purpose (including -9), with experience
294                      level breakdowns.  Sunday, sept. 23/89
295
296                  NOTE: GROUPS ARE NOT INCLUDED!
297
298     DATA LIST FILE='DATA.BUS88(21,244)'
299         /route 16-17 ngroup 31 trip 37-38 exp 43-44 wait 53-55
300     select if (route ne 39)
301     select if (ngroup eq 1)
302     recode trip (3,4,5=3)
303     recode exp (0,1=0)
304     recode exp(2 thru 20=5)
305     COMPUTE rtwait=sqrt(WAIT)
306     sort cases by trip exp
307     split file by trip exp
308     frequencies vars=wait rtwait
309         /statistics=mean mode skewness kurtosis default
310     finish
311     comment
312     comment      F-test and T-test for all each trip purpose
313                      against each other.
314                      Wednesday, Sept 13, 1989.
315
316                  NOTE: GROUPS ARE NOT INCLUDED!
317
318     DATA LIST FILE='DATA.BUS88(21,244)'
319         /route 16-17 ngroup 31 trip 37-38 wait 53-55
320     select if (trip ne -9)
321     select if (route ne 39)
322     select if (ngroup eq 1)
323     recode trip (3,4,5=3)
324     COMPUTE rtwait=sqrt(WAIT)
325     T-test groups=trip(1,2)/variable=rtwait
326     T-test groups=trip(1,3)/variable=rtwait
327     T-test groups=trip(2,3)/variable=rtwait
328     finish
329     comment
330     comment      Frequency distribution and diagnostic statistics
331                      for all trip purposes.
332                      Saturday, Sept.9, 1989.
333
334                  NOTE: GROUPS ARE NOT INCLUDED!
335
336     DATA LIST FILE='DATA.BUS88(21,244)'
337         /route 16-17 ngroup 31 trip 37-38 wait 53-55
338     select if (trip ne -9)
339     select if (route ne 39)
340     select if (ngroup eq 1)
341     COMPUTE rtwait=sqrt(WAIT)
342     frequencies vars=wait rtwait
343         /statistics=mean mode skewness kurtosis default
344     finish
345     comment
346     comment
347     comment
348              September 1, 1989
```

Listing of RUN SPSS at 20:34:40 on SEP 23, 1990 for CCid=GSA4 on UALTAMTS

```
                Frequency distribtion for exp less than 2 vs
                        experience greater than or equal to 3.

                GROUPS ARE NOT INCLUDED.

     data list file= data(bus88(21,244)
          /route 16-17 ngroup 31 exp 43-44 wait 53-55
     select if (exp ne -9)
     select if (route ne 39)
     select if (ngroup eq 1)
     compute rtwait=sqrt wait
     recode exp (0,1=0)
     recode exp(2 thru 20=5)
     sort cases by exp
     split file by exp
     frequencies vars=wait rtwait
          /statistics=mean mode skewness kurtosis default
     finish
     comment
     comment
     comment
                August 21, 1989

                F-test and t-test for experienced vs inexperienced
                        riders, for four definitions of inexperienced
                        riders.

                        - one or more trips per week
                        - two or more trips per week
                        - three or more trips per week
                        - four or more trips per week

                GROUPS ARE NOT INCLUDED!

     data list file=(data.bus88(21,244)
          /route 16-17 ngroup 31 exp 43-44 wait 53-55
     select if (exp ne -9)
     select if (route ne 39)
     select if (ngroup eq 1)
     compute rtwait=sqrt(wait)
     t-test groups=exp(4)/variables=rtwait
     t-test groups=exp(3)/variables=rtwait
     t-test groups=exp(2)/variables=rtwait
     t-test groups=exp(1)/variables=rtwait
     recode exp(4 thru 20=4)
     sort cases by exp
     split file by exp
     frequencies vars=wait rtwait
          /statistics=mean mode skewness kurtosis default
     finish
     comment
     comment
     comment      F-test and T-test for "perfect" and "imperfect"
                      schedule knowledge, WITHOUT GROUPS.

                  AUGUST 21, 1989.
```

```
Listing of RUN.SPSS at 20:34:40 on SEP 23, 1990 for CCid=GSA4 on UALTAMTS

  407     DATA LIST FILE='DATA.BUS88(21,244)'
  408         /route 16-17 ngroup 31 sched 46-47 wait 53-55
  409     select if (sched ne -9)
  410     select if (route ne 39)
  411     select if (ngroup eq 1)
  412     recode sched (2,3,4=0)
  413     COMPUTE rtwait=sqrt(WAIT)
  414     t-test groups=sched(1)/variables=rtwait
  415     sort cases by sched
  416     split file by sched
  417     frequencies vars=wait rtwait
  418         /statistics=mean mode kurtosis skewness default
  419     finish
  420     comment
  421     comment      Oneway ANOVA. Trip purpose is treatment.
  422                      trips 3, 4, & 5 combined as trip=3.
  423                      Monday, August 21, 1989.
  424
  425                  NOTE: GROUPS ARE NOT INCLUDED!
  426
  427     DATA LIST FILE='DATA.BUS88(21,244)'
  428         /route 16-17 ngroup 31 trip 37-38 wait 53-55
  429     select if (trip ne -9)
  430     select if (route ne 39)
  431     select if (ngroup eq 1)
  432     recode trip (3,4,5=3)
  433     COMPUTE rtwait=sqrt(WAIT)
  434     oneway rtwait by trip(1,3)
  435         /format=labels
  436         /contrast=-1 1 0
  437         /contrast=-1 0 1
  438         /contrast=0 -1 1
  439         /statistics=descriptives
  440     sort cases by trip
  441     split file by trip
  442     frequencies vars=wait rtwait
  443         /statistics=mean mode skewness kurtosis default
  444     finish
  445     comment
  446     comment
  447     comment
  448               August 13, 1989
  449
  450               t-test and wait and root wait distributions
  451                   "good" and "bad" weather, WITHOUT groups
  452
  453
  454     data list file='data.bus88(21,244)'
  455          /route 16-17 weather 21-22 ngroup 31 wait 53-55
  456     select if (route ne 39)
  457     select if (ngroup lt 2)
  458     recode weather (1,12=2)
  459     compute rtwait=sqrt(wait)
  460     t-test groups=weather(2)/variables=rtwait
  461     sort cases by weather
  462     split file by weather
  463     frequencies vars=wait rtwait
  464          /statistics=mean mode skewness kurtosis default
```

```
Listing of RUN.SPSS at 20:34:40 on SEP 23, 1990 for CCid=GS44 on UALTAMTS

     finish
     comment
     comment
     comment
     comment
                Aug 1, 1989

                t-test and wait and root wait distributions
                    for "good" vs "bad" weather for both group
                    and individual arrivals

                    - group arrivals treated as single
                      arrival time

                        note: new data file created for this!

     data list file='dat.bus88.gr(21,229)'
          /route 16-17 weather 21-22 ngroup 31 wait 53-55
     select if (route ne 39)
     recode weather (1,12=2)
     compute rtwait=sqrt(wait).
     recode ngroup (2,3=2)
     sort cases by ngroup
     split file by ngroup
     t-test groups=weather(2)/variables=rtwait
     finish
     comment
     comment
     comment     F-test and T-test for "perfect" and "imperfect"
                     schedule knowledge, for both "good" and
                     "bad" weather splits.   July 30, 1989.

     DATA LIST FILE='DATA.BUS88(21,244)'
          /route 16-17 weather 21-22 sched 46-47 wait 53-55
     select if (sched ne -9)
     select if (route ne 39)
     recode weather (1,12=2)
     recode sched (2,3,4=0)
     COMPUTE rtwait=sqrt(WAIT)
     descriptives variables=rtwait
          /statistics=kurtosis skewness
     t-test groups=sched(1)/variables=rtwait
     sort cases by weather
     split file by weather
     descriptives variables=rtwait
          /statistics=kurtosis skewness
     t-test groups=sched(1)/variables=rtwait
     finish
     comment
     comment     Oneway ANOVA. Trip purpose is treatment.
                     trips 3, 4, & 5 combined as trip=3.
                     Sunday, July 30,1989.

     DATA LIST FILE='DATA.BUS88(21,244)'
          /route 16-17 weather 21-22 trip 37-38 wait 53-55
     select if (trip ne -9)
     select if (route ne 39)
     recode weather (1,12=2)
```

Listing of RUN.SPSS at 20:34:40 on SEP 23, 1990 for CCid=GS44 on UALTAMTS

```
523     recode trip (3,4,5=3)
524     COMPUTE rtwait=sqrt(WAIT)
525     sort cases by weather
526     split file by weather
527     descriptives variables=rtwait
528         /statistics=kurtosis skewness
529     oneway rtwait by trip(1,3)
530         /format=labels
531         /contrast=-1 1 0
532         /contrast=-1 0 1
533         /contrast=0 -1 1
534         /statistics=descriptives
535     finish
536     comment
537     comment
538     comment
539               July 30, 1989
540
541               F-test and t-test for experienced vs inexperienced
542                     riders, for four definitions of inexperienced
543                     riders and "good" and "bad" weather split:
544
545                     - one or more trips per week
546                     - two or more trips per week
547                     - three or more trips per week
548                     - four or more trips per week
549
550
551     data list file='data.bus88(21,244)'
552          /route 16-17 weather 21-22 exp 43-44 wait 53-55
553     select if (route ne 39)
554     select if (exp ne -9)
555     compute rtwait=sqrt(wait)
556     recode weather (1,12=2)
557     sort cases by weather
558     split file by weather
559     t-test groups=exp(4)/variables=rtwait
560     t-test groups=exp(3)/variables=rtwait
561     t-test groups=exp(2)/variables=rtwait
562     t-test groups=exp(1)/variables=rtwait
563     finish
564     comment
565     comment
566     comment
567     comment
568               July 30, 1989
569
570               t-test and wait and root wait distributions
571                   for groups vs. individuals for both "good"
572                   and "bad" weather
573
574                   - group arrivals treated as single
575                     arrival time
576
577                     note: new data file created for this!
578
579     data list file='dat.bus88.gr(21,229)'
580          /route 16-17 weather 21-22 ngroup 31 wait 53-55
```

```
Listing of RUN SPSS at 20:34:40 on SEP 23, 1990 for CCid=GS44 on UALTAMTS

   581      select if (route ne 39)
   582      recode weather (1,12=2)
   583      compute rtwait=sqrt(wait)
   584      sort cases by weather
   585      split file by weather
   586      t-test groups=ngroup(2)/variables=rtwait
   587      split file off
   588      recode ngroup (2,3=2)
   589      sort cases by weather ngroup
   590      split file by weather ngroup
   591      frequencies vars=wait rtwait
   592           /statistics=mean mode skewness kurtosis default
   593      finish
   594      comment
   595      comment
   596      comment
   597                July 2, 1989
   598
   599                1. Overall wait and root wait distributions
   600                   and statistical parameters.
   601
   602                2. F-test and t-test for good vs bad weather.
   603
   604                3. F-test and t-test for experienced vs inexperienced
   605                        riders, for four definitions of inexperienced
   606                        riders:
   607
   608                          - one or more trips per week
   609                          - two or more trips per week
   610                          - three or more trips per week
   611                          - four or more trips per week
   612
   613
   614      data list file='data.bus88(21,244)'
   615           /route 16-17 weather 21-22 exp 43-44 wait 53-55
   616      select if (route ne 39)
   617      compute rtwait=sqrt(wait)
   618      frequencies vars=wait rtwait
   619           /statistics=mean mode skewness kurtosis default
   620      recode weather (1,12=2)
   621      t-test groups=weather(2)/variables=rtwait
   622      select if (exp ne -9)
   623      t-test groups=exp(4)/variables=rtwait
   624      t-test groups=exp(3)/variables=rtwait
   625      t-test groups=exp(2)/variables=rtwait
   626      t-test groups=exp(1)/variables=rtwait
   627      finish
   628      comment
   629      comment
   630      comment
   631                July 2, 1989
   632
   633                t-test and wait and root wait distributions
   634                   for groups vs. individuals
   635
   636                   - group arrivals treated as single
   637                     arrival time
   638
```

Listing of RUN.SPSS at 20:34:40 on SEP 23, 1990 for CCid=GSA4 on UALTAMTS

```
639                          note: new data file created for this!
640
641     data list file='dat.bus88.gr(21,229)'
642          /route 16-17 ngroup 31 wait 53-55
643     select if (route ne 39)
644     compute rtwait=sqrt(wait)
645     t-test groups=ngroup(2)/variables=rtwait
646     recode ngroup (2,3=2)
647     sort cases by ngroup
648     split file by ngroup
649     frequencies vars=wait rtwait
650          /statistics=mean mode skewness kurtosis default
651     finish
652     comment
653     comment
654     comment
655               ONEWAY analysis for:
656                    1. Two levels of experience
657                    2. Groups/Individuals
658                    3. Perfect/No Schedule Knowledge
659               Saturday, April 29, 1989.
660
661     DATA LIST FILE='DATA.BUS88(21,244)'
662          /route 16-17 ngroup 31
663           exp 43-44 sched 46-47 wait 53-55
664     select if (exp ne -9)
665     select if (route ne 39)
666     select if (sched ne -9)
667     COMPUTE rtwait=sqrt(WAIT)
668     recode exp (0,1,2,3=0)(4 thru 15=1)
669     recode sched (2,3,4=0)
670     recode ngroup (2,3=2)
671     sort cases by exp
672     split file by exp
673     descriptives variables=rtwait
674          /statistics=kurtosis skewness
675     split file off
676     oneway rtwait by exp(0,1)
677          /format=labels
678          /contrast=-1 1
679          /statistics=descriptives
680     sort cases by ngroup
681     split file by ngroup
682     descriptives variables=rtwait
683          /statistics=kurtosis skewness
684     split file off
685     oneway rtwait by ngroup(1,2)
686          /format=labels
687          /contrast=-1 1
688          /statistics=descriptives
689     sort cases by sched
690     split file by sched
691     descriptives variables=rtwait
692          /statistics=kurtosis skewness
693     split file off
694     oneway rtwait by sched(0,1)
695          /format=labels
696          /contrast=-1 1
```

Listing of RUN.SPSS at 20:34:40 on SEP 23, 1990 for CCid=GS44 on UALTAMTS

```
697         /statistics=descriptives
698     finish
699     comment
700     comment      Oneway ANOVA. Trip purpose is treatment.
701                      trips 3, 4, & 5 combined as trip=3.
702                      Saturday, April 29, 1989.
703
704     DATA LIST FILE='DATA.BUS88(21,244)'
705         /route 16-17 trip 37-38
706          wait 53-55
707     select if (trip ne -9)
708     select if (route ne 39)
709     recode trip (3,4,5=3)
710     COMPUTE rtwait=sqrt(WAIT)
711     descriptives variables=rtwait
712         /statistics=kurtosis skewness
713     oneway rtwait by trip(1,3)
714         /format=labels
715         /contrast=-1 1 0
716         /contrast=-1 0 1
717         /contrast=0 -1 1
718         /statistics=descriptives
719     finish
720     comment
721     comment
722               distributions for two levels of experience
723               (0,1,2,3=0/4+=5) April 23/89.
724
725     DATA LIST FILE='DATA.BUS88(21,244)'
726         /route 16-17
727          exp 43-44 wait 53-55
728     select if (exp ne -9)
729     select if (route ne 39)
730     COMPUTE rtwait=sqrt(WAIT)
731     recode exp (0,1,2,3=0)(4 thru 15=5)
732     sort cases by exp
733     split file by exp
734     frequencies vars=wait rtwait
735         /statistics=mean mode skewness kurtosis default
736     finish
737     comment   Wait time and square root wait time frequency
738               distributions for groups/individuals.
739               perfect/no schedule knowledge and six levels of
740               experience (-9,0,1,2,3,4+).  April 23/89.
741
742     DATA LIST FILE='DATA.BUS88(21,244)'
743         /route 16-17 ngroup 31
744          exp 43-44 sched 46-47 wait 53-55
745     select if (route ne 39)
746     COMPUTE rtwait=sqrt(WAIT)
747     recode exp (-9=-9)(0=0)(1=1)(2=2)(3=3)(4 thru 15=5)
748     recode sched (2,3,4=0)
749     recode ngroup (2,3=2)
750     sort cases by ngroup
751     split file by ngroup
752     frequencies vars=wait rtwait
753         /statistics=mean mode skewness kurtosis default
754     split file off
```

Listing of RUN.SPSS at 20:34:40 on SEP 23, 1990 for CCid=GSA4 on UALTAMTS

```
sort cases by sched
split file by sched
frequencies vars=wait rtwait
     /statistics=mean mode skewness kurtosis default
split file off
sort cases by exp
split file by exp
frequencies vars=wait rtwait
     /statistics=mean mode skewness kurtosis default
split file off
finish
comment      Oneway ANOVA. Trip purpose is treatment,
                Sunday April 23/89.


DATA LIST FILE='DATA.BUS88(21,244)'
    /route 16-17 trip 37-38
     wait 53-55
select if (trip ne -9)
select if (route ne 39)
COMPUTE rtwait=sqrt(WAIT)
descriptives variables=rtwait
    /statistics=kurtosis skewness
oneway rtwait by trip(1,5)
    /format=labels
    /contrast=-1 1 0 0 0
    /contrast=-2 .5 .5 .5 .5
    /contrast=.5 -2 .5 .5 .5
    /contrast=.5 .5 -2 .5 .5
    /contrast=.5 .5 .5 -2 .5
    /contrast=.5 .5 .5 .5 -2
    /statistics=descriptives
finish
comment
comment
comment      Oneway ANOVA. Trip purpose is treatment,
                data is split into good and bad weather
                cases.  Friday April 14/89.


DATA LIST FILE='DATA.BUS88(21,244)'
    /route 16-17 weather 22 ngroup 31 trip 37-38
     exp 43-44 sched 46-47 wait 53-55
select if (trip ne -9)
select if (route ne 39)
COMPUTE rtwait=sqrt(WAIT)
recode weather (1,12=2)
sort cases by weather
split file by weather
descriptives variables=rtwait
    /statistics=kurtosis skewness
oneway rtwait by trip(1,5)
    /format=labels
    /contrast=-1 .25 .25 .25 .25
    /contrast=.25 -1 .25 .25 .25
    /contrast=.25 .25 -1 .25 .25
    /contrast=.25 .25 .25 -1 .25
    /contrast=.25 .25 .25 .25 -1
```

Listing of RUN.SPSS at 20:34:40 on SEP 23, 1990 for CCid=GSA4 on UALTAMTS

```
 813          /statistics=descriptives
 814      finish
 815      comment
 816      comment
 817      comment    Wait time and square root wait time frequency
 818                 distributions for each weather type and
 819                 experience level (March 29, 1989).
 820
 821
 822      DATA LIST FILE='DATA.BUS88(21,244)'
 823          /route 16-17 weather 21-22
 824           exp 43-44 wait 53-55
 825      select if (route ne 39)
 826      COMPUTE rtwait=sqrt(WAIT)
 827      recode weather (1,12=2)
 828      recode exp (1=0)(5 thru 15=5)
 829      sort cases by weather exp
 830      split file by weather exp
 831      frequencies vars=wait rtwait
 832           /statistics=mean mode skewness kurtosis default
 833      finish
 834      comment
 835      comment
 836      comment    Wait time and square root wait time frequency
 837                 distributions for combinations of weather,
 838                 trip purpose, experience, and schedule knowledge.
 839
 840
 841      DATA LIST FILE='DATA.BUS88(21,244)'
 842          /route 16-17 weather 22 ngroup 31 trip 37-38
 843           exp 43-44 sched 46-47 wait 53-55
 844      select if (route ne 39)
 845      COMPUTE rtwait=sqrt(WAIT)
 846      recode weather (1,12=2)
 847      recode exp (1=0)(2 thru 15=5)
 848      recode sched (2,3,4=0)
 849      recode ngroup (2,3=10)
 850      sort cases by weather
 851      split file by weather
 852      frequencies vars=wait rtwait
 853           /statistics=mean mode skewness kurtosis default
 854      split file off
 855      sort cases by weather trip
 856      split file by weather trip
 857      frequencies vars=wait rtwait
 858           /statistics=mean mode skewness kurtosis default
 859      split file off
 860      sort cases by weather sched
 861      split file by weather sched
 862      frequencies vars=wait rtwait
 863           /statistics=mean mode skewness kurtosis default
 864      split file off
 865      sort cases by weather exp
 866      split file by weather exp
 867      frequencies vars=wait rtwait
 868           /statistics=mean mode skewness kurtosis default
 869      split file off
 870      sort cases by weather ngroup
```

Listing of RUN.SPSS at 20:34.40 on SEP 23, 1990 for CCid=GS44 on JALTAMTS

```
split file by weather ngroup
frequencies vars=wait rtwait
     statistics=mean mode skewness kurtosis default
split file off
sort cases by weather trip exp
split file by weather trip exp
frequencies vars=wait rtwait
     /statistics=mean mode skewness kurtosis default
split file off
sort cases by weather trip sched
split file by weather trip sched
frequencies vars=wait rtwait
     /statistics=mean mode skewness kurtosis default
split file off
sort cases by weather exp sched
split file by weather exp sched
frequencies vars=wait rtwait
     /statistics=mean mode skewness kurtosis default
split file off
sort cases by weather trip exp sched
split file by weather trip exp sched
frequencies vars=wait rtwait
     /statistics=mean mode skewness kurtosis default
finish
comment
comment
comment   Wait time frequency distributions for
          each observed stop with passengers.


DATA LIST FILE='DATA.BUS88(21,244)'
    /date 12-13 route 16-17 WAIT 53-55
COMPUTE rtwait=sqrt(WAIT).
sort cases by date route
split file by date route
frequencies vars=wait rtwait
     /statistics=mean mode default
finish
comment
comment
comment
DATA LIST FILE='DATA.BUS88(21,244)'
    /WAIT 53-55
COMPUTE LOGWAIT=LG10(WAIT)
COMPUTE RTWAIT=SQRT(WAIT)
CONDESCRIPTIVE WAIT LOGWAIT RTWAIT
STATISTICS 2 6 9 13 7 8.
COMMENT the next line selects waits greater than
   or equal to 20s for analysis.  In effect, most
   "causually coincidental" arrivals are discluded.

   NOTE:  This is different from the last analysis
          (Jan 14/89), where "Select if (wait ge 5)"
          was used.

SELECT IF (WAIT GE 20)
COMPUTE LOGWAIT=LG10(WAIT)
COMPUTE RTWAIT=SQRT(WAIT)
```

Listing of RUN.SPSS at 20:34:40 on SEP 23, 1990 for CC1d=GS44 on UALTAMTS

```
929     CONDESCRIPTIVE WAIT LOGWAIT RTWAIT
930     STATISTICS 2 6 9 13 7 8 .
931     FREQUENCIES VARS=WAIT LOGWAIT RTWAIT
932         /STATISTICS=MEDIAN MODE DEFAULT
933     FINISH
934     comment
935     comment
936     comment
937     DATA LIST FILE='DATA.BUS88(21,244)'
938         /WAIT 53-55
939     COMMENT the next line selects waits greater than
940        or equal to 5s for analysis.  In effect, all
941        zero waits are discluded.
942     SELECT IF (WAIT GE 5)
943     COMPUTE LOGWAIT=LG10(WAIT)
944     COMPUTE RTWAIT=SQRT(WAIT)
945     CONDESCRIPTIVE WAIT LOGWAIT RTWAIT
946     STATISTICS 2 6 9 13
947     FREQUENCIES VARS=WAIT LOGWAIT RTWAIT
948         /STATISTICS=MEDIAN MODE DEFAULT
949     FINISH
950     comment
951     comment
952     comment
953     DATA LIST FILE='DATA.BUS88(21,244)'
954         /WAIT 53-55
955     COMPUTE LOGWAIT=LG10(WAIT)
956     COMPUTE RTWAIT=SQRT(WAIT)
957     COMMENT the next two commands compute stats for the
958         mean, standard deviation, min. score, max. score,
959         standard error of the mean, variance and range for the
960         actual wait time, log wait time, and square root
961         wait time data sets.
962     DESCRIPTIVES WAIT LOGWAIT RTWAIT
963       /STATISTICS=SEMEAN VARIANCE RANGE MEAN STDDEV MIN MAX
964     COMMENT will the frequencies command work for
965         data values with a range of 0 to 2 (i.e.
966         logwait and square root wait data)?  YES!
967     FREQUENCIES VARS=WAIT LOGWAIT RTWAIT
968         /STATISTICS=MEDIAN MODE DEFAULT
969     FINISH
970     comment
971     comment
972     comment
973     DATA LIST FILE='DATA.BUS88(20,242)'
974         /DAY 4-6(A) MONTH 8-10(A) DATE 12-13 ROUTE 16-17
975          WEATHER 22 NGROUP 31 TRIP 38 EXP 44 SCHED 47 WAIT 53-55
976     descriptive date to wait
977     ONEWAY WAIT BY WEATHER(0,2)
978     ONEWAY WAIT BY WEATHER(0,1)
979     ONEWAY WAIT BY WEATHER(1,2)
980     RECODE WEATHER(0=0)(1,2=2) into dweather
981     ONEWAY WAIT BY dWEATHER(0,2)
982     RECODE WEATHER(0,1=0)(2=2) into dweath2
983     ONEWAY WAIT BY dWEATH2(0,2)
984     FREQUENCIES VARS=WAIT
985     finish
```

Appendix E: Objective Weather Data

The following table shows the objective weather data for each day of observations. The objective weather data consist of the air temperature recorded from radio broadcast shortly before observations commenced, and the daily maximum air temperature recorded by weather monitoring stations. Also shown is the subjective data for each day of observations.

Generally, "Bad" weather days tended to fall on days were the temperature was lower. There is some overlap. This may be attributed to temperatures lowering during the autumn, but then increasing near the end of the observation period. Thus days with similar temperatures at the end of the observation period as compared to earlier observations, were classified as "Good" weather, as passengers seemed to become acclimatized to these temperatures.

Stop Description	Date and Time Surveyed	"Objective" Mean Temperature	"Subjective" Temperature	"Subjective" Weather Classification
Route 29 SBD, 152 Ave – 118 St	Sat, Oct 29, 1100–1235	-2.2	2	"Good"
	Sat, Nov 12, 1220–1310	-7.2	-7	"Bad"
Route 30 NBD, 179 Ave – 95 St	Mon, Oct 31, 0640–0755	3.5	-1	"Good"
Route 18 WBD, 118 Ave – 34 St	Mon, Oct 31, 0915–1015	3.5	2	"Good"
Route 43 EBD, 47 Ave – 106A St	Tues, Nov 1, 0555–0810	4.3	3	"Good"
Route 5 EBD, 114 Ave – 131 St	Tues, Nov 1, 0930–1010	4.3	3	"Good"
Route 29 WBD, 152 Ave – 114 St	Sat, Nov 5, 1005–1050	2.8	3	"Good"
Route 39 NBD, 84 Ave – 178 St	Mon, Nov 7, 0645–0810	0.7	-1	"Bad"
Route 5 WBD, 114 Ave – 124 St	Mon, Nov 7, 0850–0955	0.7	-1	"Bad"
	Mon, Nov 14, 1145–1345	-6.1	-6	"Bad"
Route 43 EBD, 47 Ave – 106 St	Tues, Nov 8 0555–0840	-2.5	-3	"Bad"
Route 29 SBD, 147 Ave – 118 St	Tues, Nov 8, 1055–1125	-2.5	2	**
Route 30 NBD, 174 Ave – 95 St	Mon, Nov 14, 0640–0755	-6.1	-7	"Bad"
Route 3 SBD, 117 Ave – 124 St	Tues, Nov 15, 0625–0740	-6.5	-4	"Bad"
Route 29 SBD, 145 Ave – 118 St	Tues, Nov 15, 0825–0925	-6.5	-6	"Bad"
Route 5 EBD, 114 Ave – Groat Rd	Sat, Nov 19, 1100–1145	-4.5	-4	**
Route 30 NBD, 171 Ave – 95 St	Mon, Nov 21, 0640–0755	-4.0	-8	"Bad"
Route 43 WBD, 47 Ave – 106 St	Tues, Nov 22, 0655–0830	-2.5	-5	"Bad"
Route 30 NBD, 176 Ave – 95 St	Mon, Nov 28, 0625–0756	-3.2	-5	"Good"
Route 43 WBD, 47 Ave – 106A St	Tues, Nov 29, 0700–0830	0.2	-3	"Good"

** No passenger arrivals, thus no weather classification.

"Objective" Mean Temperature: Mean of daily high and low temperatures in degrees Centigrade, as recorded by Environment Canada, Atmospheric Environment Service at the Edmonton Municipal Airport weather station.

"Subjective" Temperature: Temperature (in degrees Centigrade) recorded by observer immediately before observations commenced, from a local radio station.